US009392140B2

(12) **United States Patent**
Kawano

(10) **Patent No.: US 9,392,140 B2**
(45) **Date of Patent: Jul. 12, 2016**

(54) **IMAGE PROCESSING APPARATUS**

(71) Applicant: **FUJI XEROX CO., LTD.**, Tokyo (JP)

(72) Inventor: **Hiroyuki Kawano**, Kanagawa (JP)

(73) Assignee: **FUJI XEROX CO., LTD.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/605,002**

(22) Filed: **Jan. 26, 2015**

(65) **Prior Publication Data**

US 2016/0088186 A1 Mar. 24, 2016

(30) **Foreign Application Priority Data**

Sep. 22, 2014 (JP) 2014-192403

(51) **Int. Cl.**
H04N 1/04 (2006.01)
H04N 1/409 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 1/409*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 1/409
USPC 358/1.9, 1.14, 1.15
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0026085 A1* 2/2011 Tsukahara H04N 1/1903 358/482

FOREIGN PATENT DOCUMENTS

JP 56-80963 A 7/1981
JP 3-128566 A 5/1991
JP 2010-178174 A 8/2010

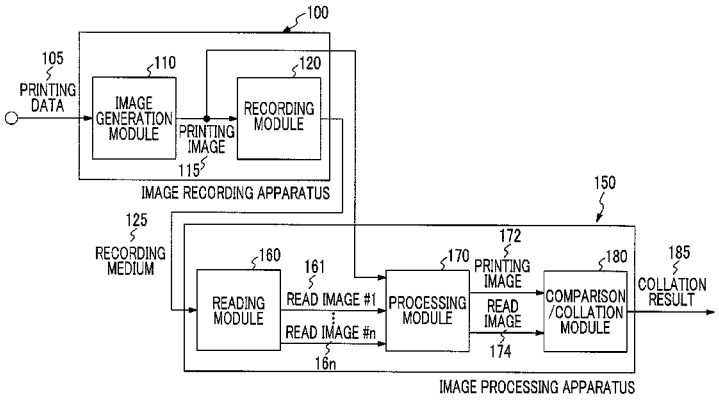
* cited by examiner

Primary Examiner — Houshang Safaipour
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

Provided is an image processing apparatus including a correction unit that corrects a tilt of each partial image data item which is a result of plural sensors reading a medium on which an image of image data is formed so that at least part of a reading region which is read by each of the plural sensors overlaps a reading region of an adjacent sensor, an extraction unit that extracts the image data at a position and in a size at and in which the image data matches the respective partial image data, and a comparison unit that compares partial image data corrected by the correction unit with extracted image data extracted by the extraction unit.

5 Claims, 16 Drawing Sheets



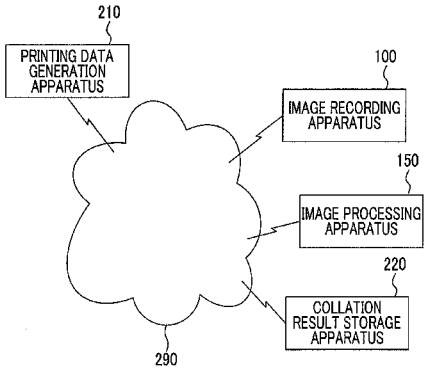


FIG. 1

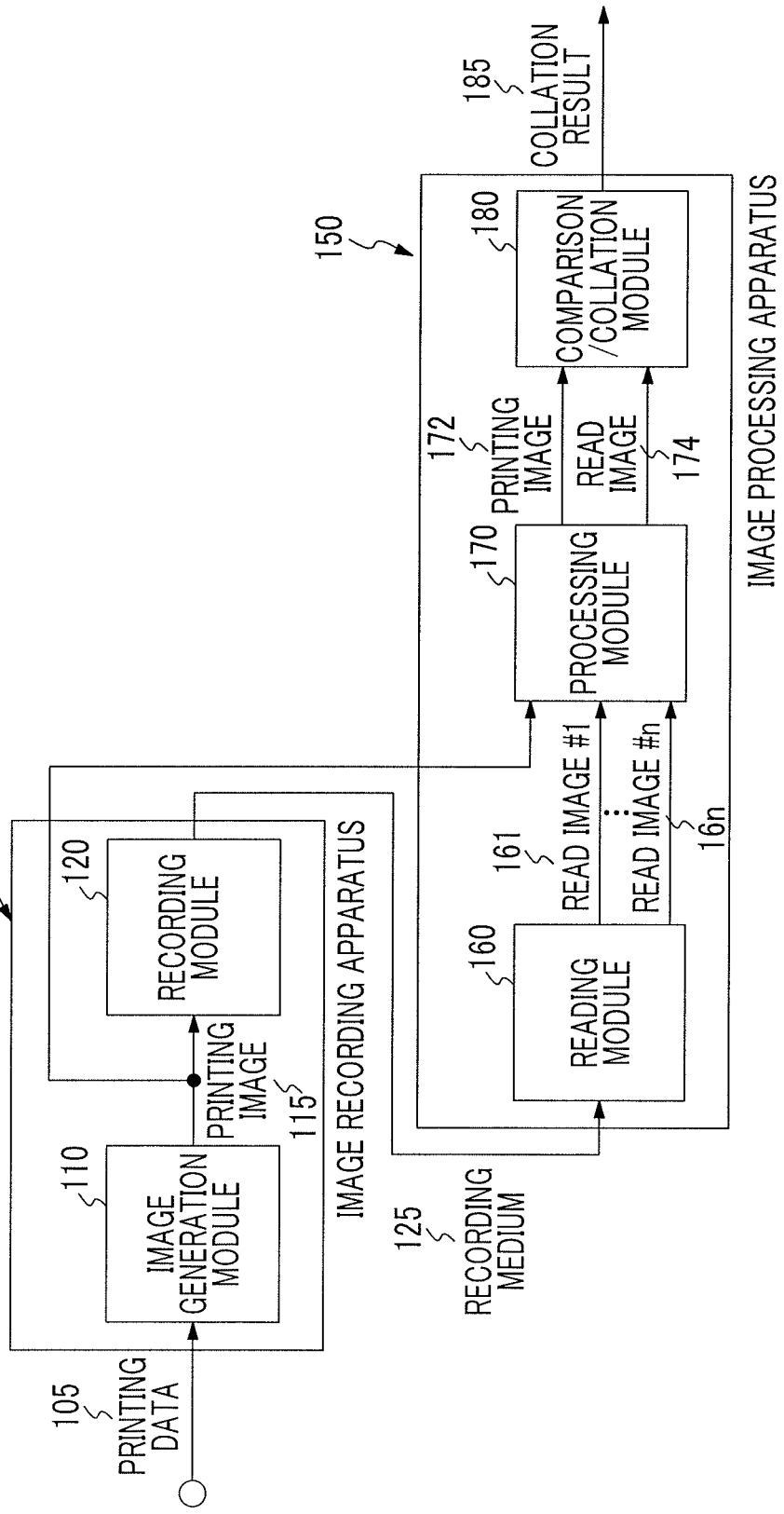

105
PRINTING DATA
100
110
IMAGE GENERATION MODULE
115
PRINTING IMAGE
120
RECORDING MODULE
IMAGE RECORDING APPARATUS
125
RECORDING MEDIUM
150
160
READING MODULE
161
READ IMAGE #1
READ IMAGE #n
16n
170
PROCESSING MODULE
172
PRINTING IMAGE
READ IMAGE
174
180
COMPARISON /COLLATION MODULE
185
COLLATION RESULT
IMAGE PROCESSING APPARATUS

FIG. 2

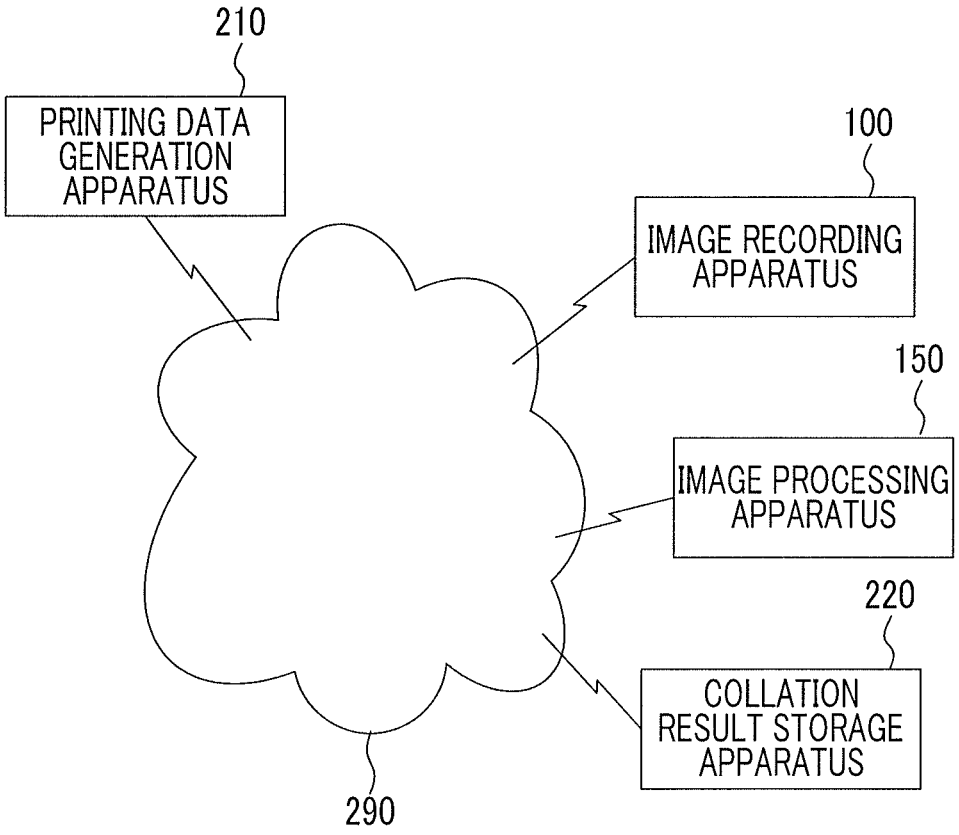

210
PRINTING DATA GENERATION APPARATUS
100
IMAGE RECORDING APPARATUS
150
IMAGE PROCESSING APPARATUS
220
COLLATION RESULT STORAGE APPARATUS
290

FIG. 3

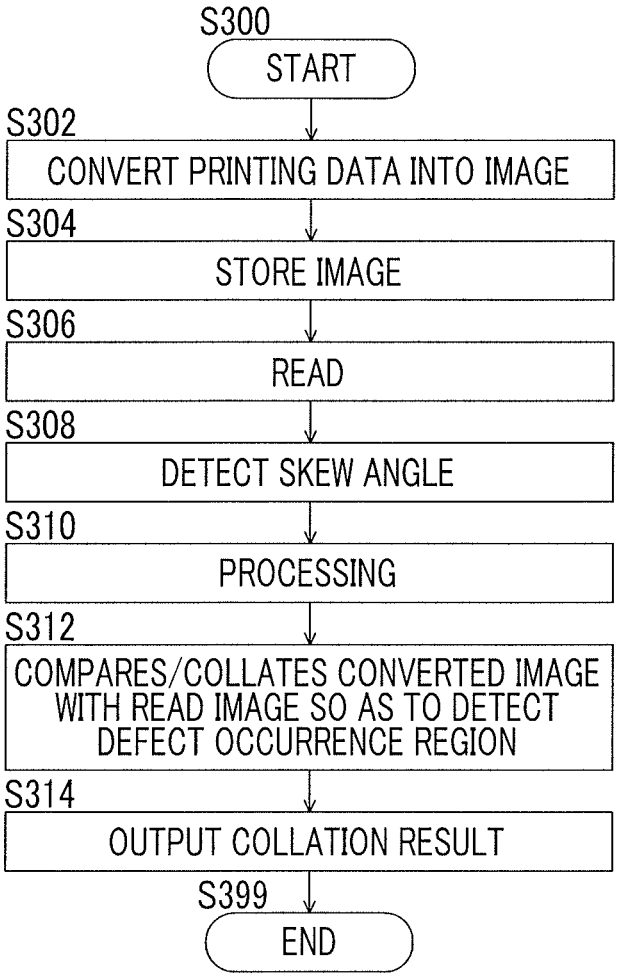

S300
START
S302
CONVERT PRINTING DATA INTO IMAGE
S304
STORE IMAGE
S306
READ
S308
DETECT SKEW ANGLE
S310
PROCESSING
S312
COMPARES/COLLATES CONVERTED IMAGE WITH READ IMAGE SO AS TO DETECT DEFECT OCCURRENCE REGION
S314
OUTPUT COLLATION RESULT
S399
END

FIG. 4

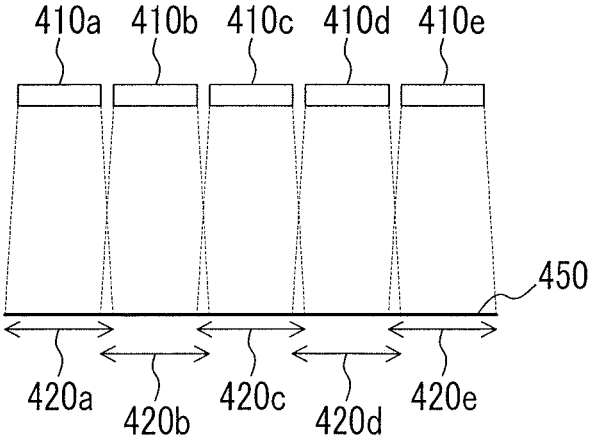

410a
410b
410c
410d
410e
450
420a
420b
420c
420d
420e

FIG. 5

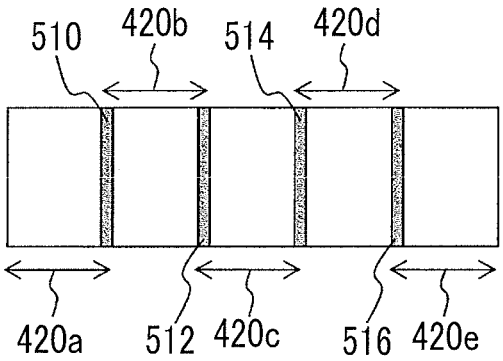


FIG. 6

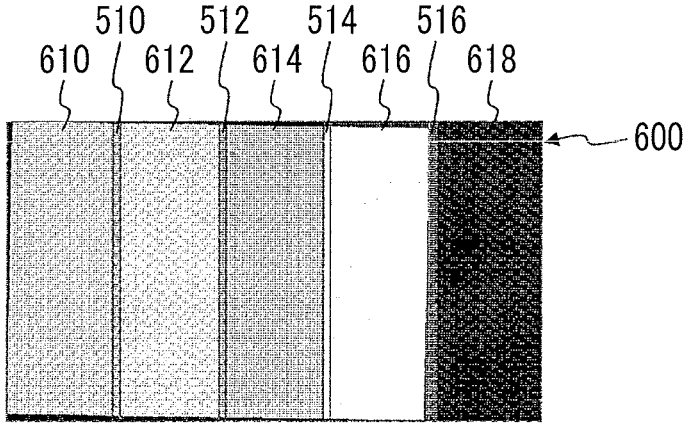


FIG. 7

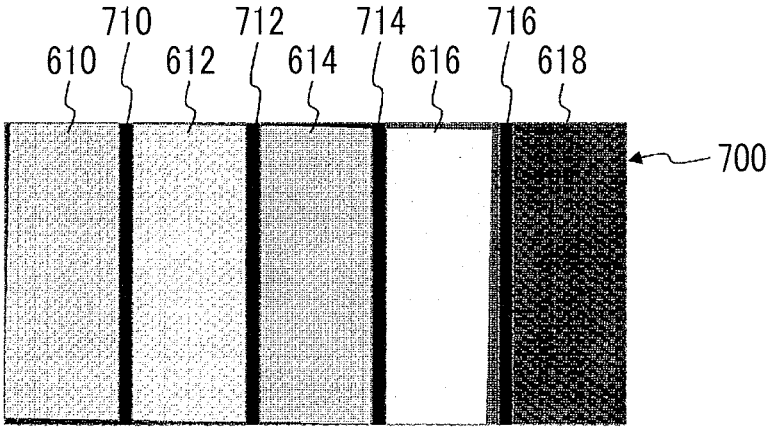


FIG. 8

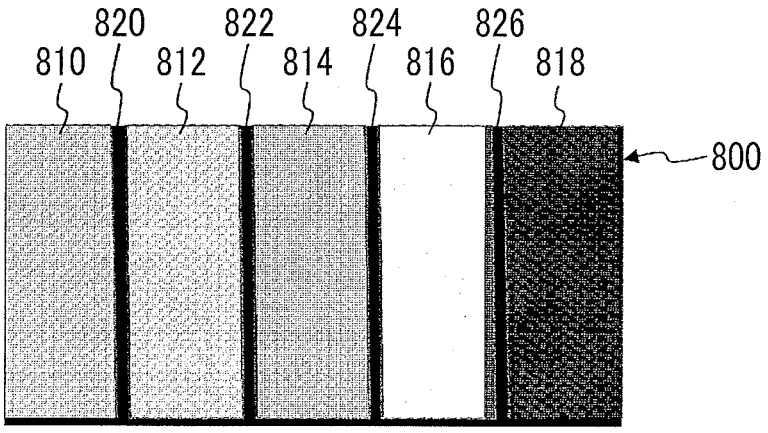


FIG. 9A

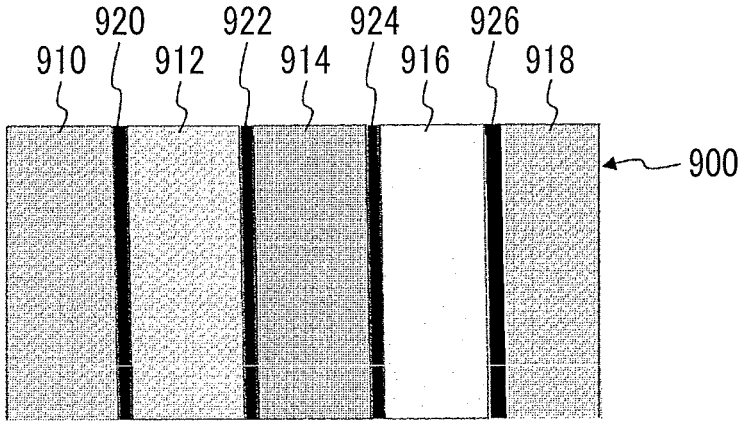

920
922
924
926
910
912
914
916
918
900

FIG. 9B

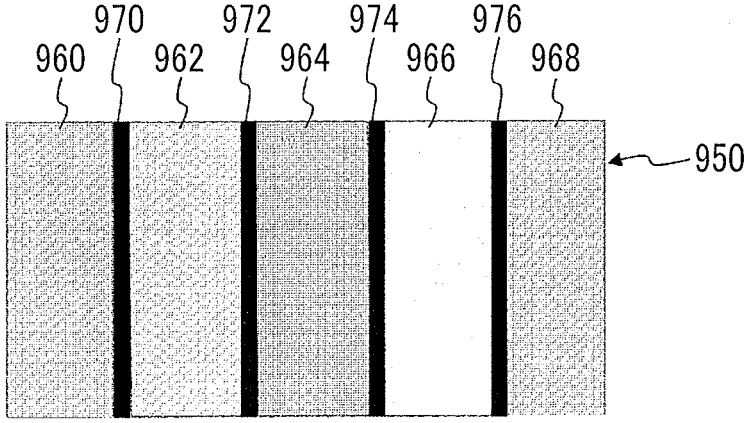

970
972
974
976
960
962
964
966
968
950

FIG. 10

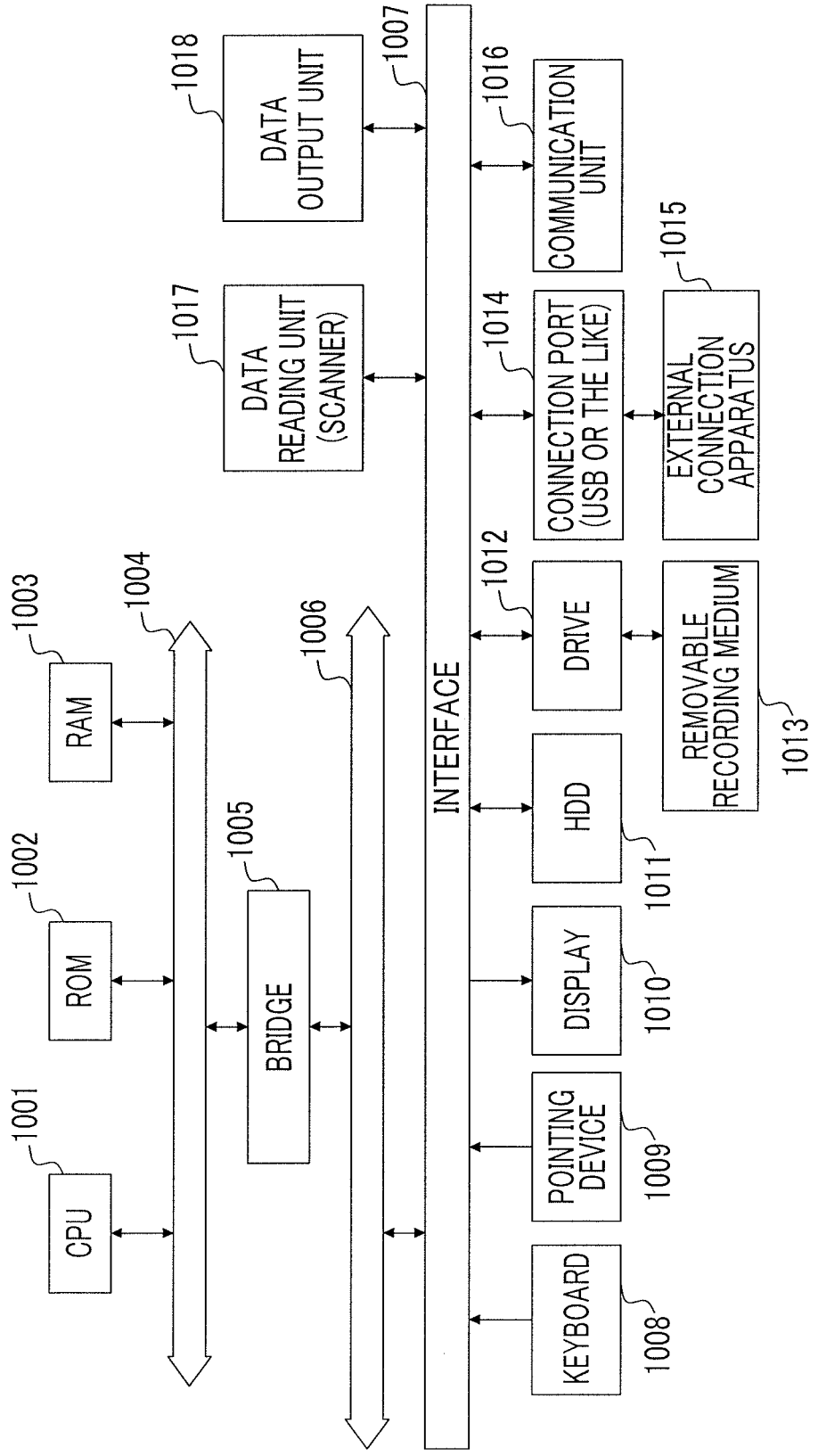

CPU
1001
ROM
1002
RAM
1003
BRIDGE
1005
1004
1006
INTERFACE
1007
KEYBOARD
1008
POINTING DEVICE
1009
DISPLAY
1010
HDD
1011
DRIVE
1012
REMOVABLE RECORDING MEDIUM
1013
CONNECTION PORT (USB OR THE LIKE)
1014
EXTERNAL CONNECTION APPARATUS
1015
COMMUNICATION UNIT
1016
DATA READING UNIT (SCANNER)
1017
DATA OUTPUT UNIT
1018

FIG. 11

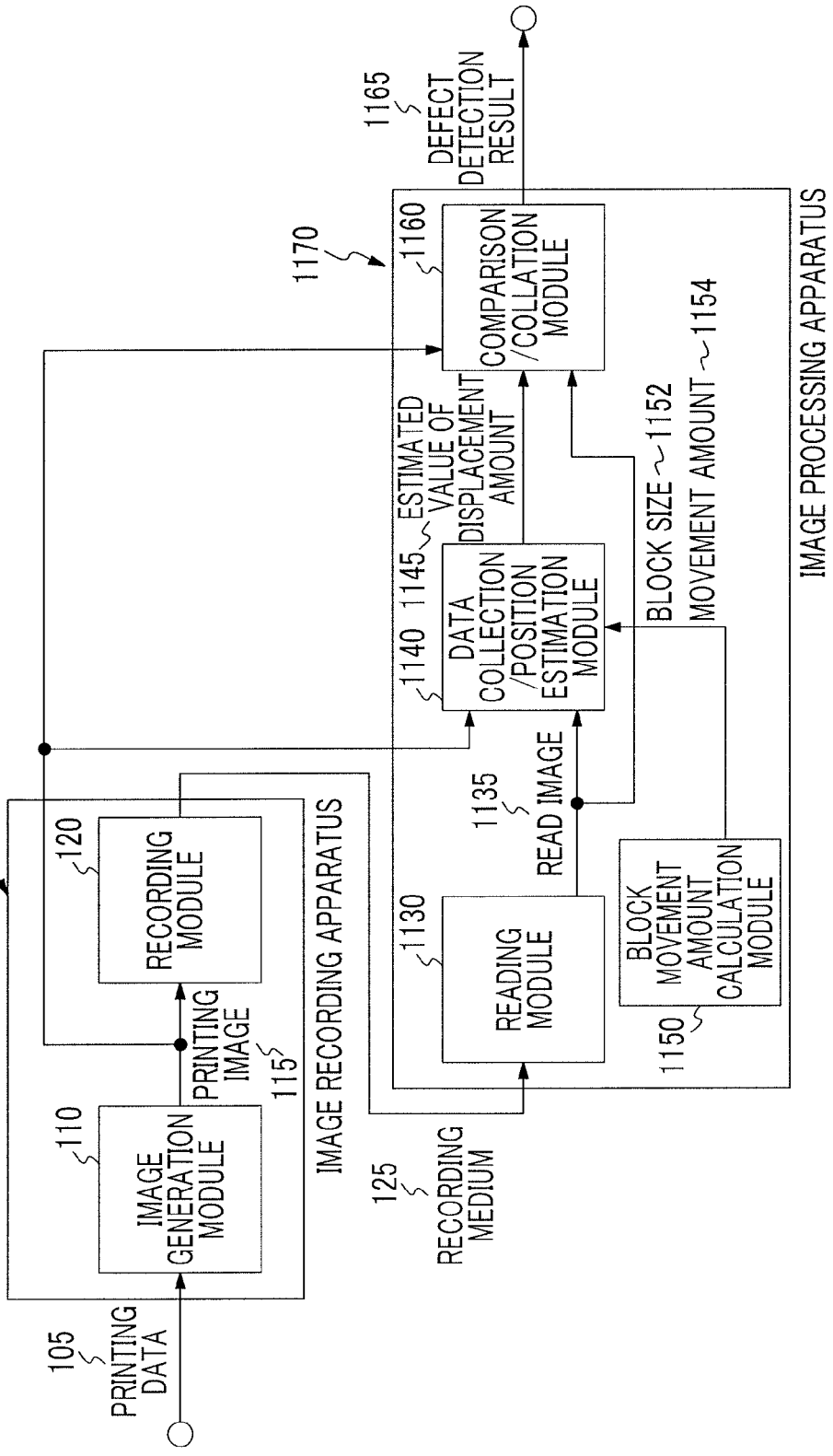

105
PRINTING DATA
100
110
IMAGE GENERATION MODULE
PRINTING IMAGE
115
120
RECORDING MODULE
IMAGE RECORDING APPARATUS
125
RECORDING MEDIUM
1130
READING MODULE
1135
READ IMAGE
1140
1145
DATA COLLECTION /POSITION ESTIMATION MODULE
ESTIMATED VALUE OF DISPLACEMENT AMOUNT
1150
BLOCK MOVEMENT AMOUNT CALCULATION MODULE
BLOCK SIZE
MOVEMENT AMOUNT
1152
1154
1160
COMPARISON /COLLATION MODULE
1165
DEFECT DETECTION RESULT
1170
IMAGE PROCESSING APPARATUS

FIG. 12

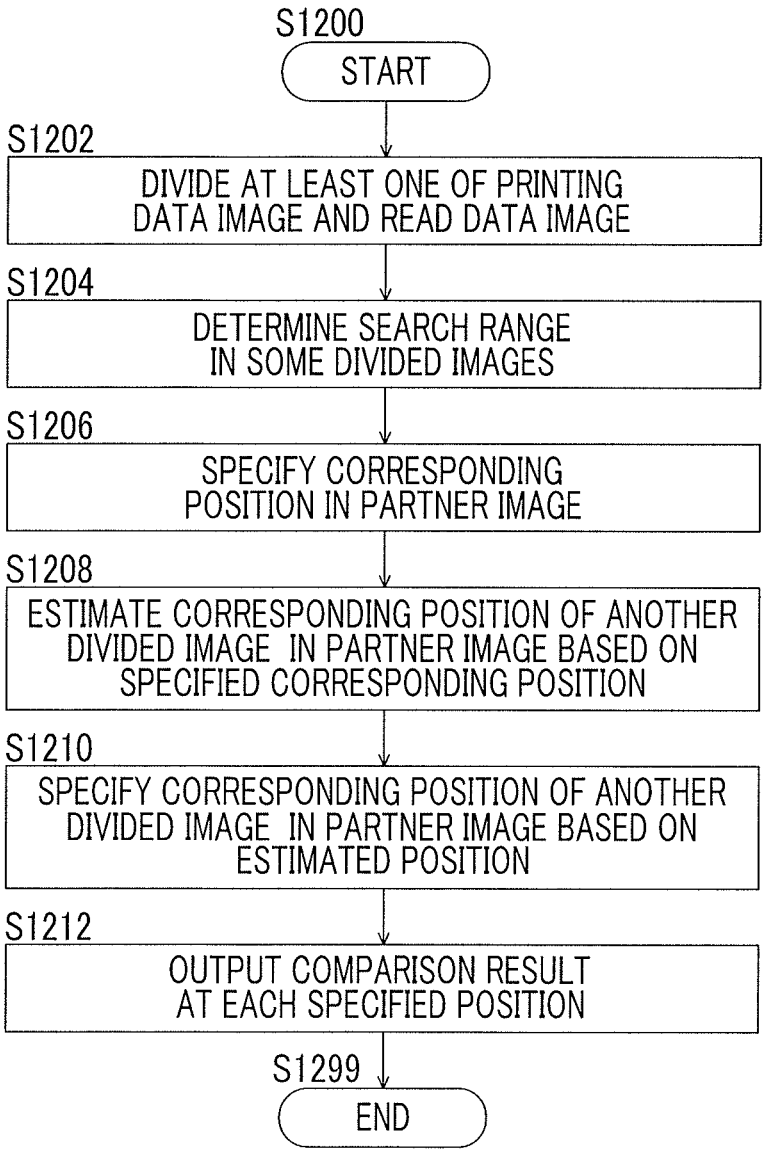

S1200
START
S1202
DIVIDE AT LEAST ONE OF PRINTING DATA IMAGE AND READ DATA IMAGE
S1204
DETERMINE SEARCH RANGE IN SOME DIVIDED IMAGES
S1206
SPECIFY CORRESPONDING POSITION IN PARTNER IMAGE
S1208
ESTIMATE CORRESPONDING POSITION OF ANOTHER DIVIDED IMAGE IN PARTNER IMAGE BASED ON SPECIFIED CORRESPONDING POSITION
S1210
SPECIFY CORRESPONDING POSITION OF ANOTHER DIVIDED IMAGE IN PARTNER IMAGE BASED ON ESTIMATED POSITION
S1212
OUTPUT COMPARISON RESULT AT EACH SPECIFIED POSITION
S1299
END

FIG. 13A FIG. 13B FIG. 13C

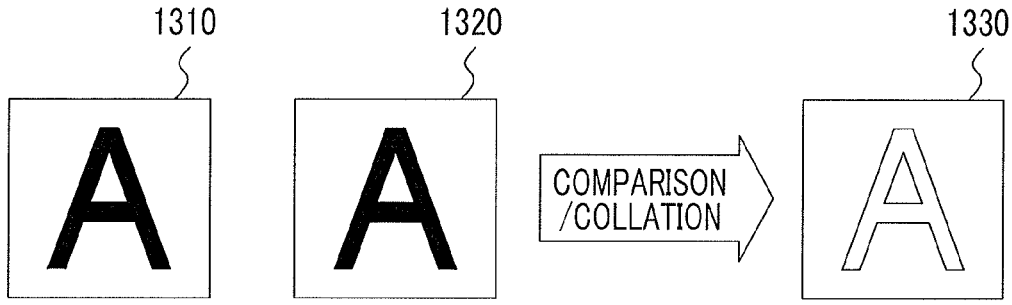


FIG. 14

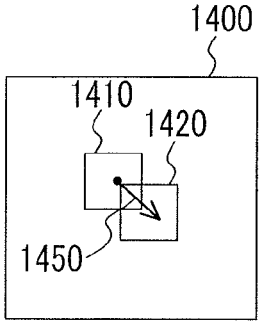


FIG. 15A

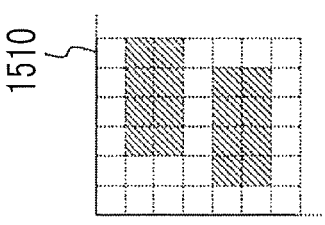


FIG. 15B

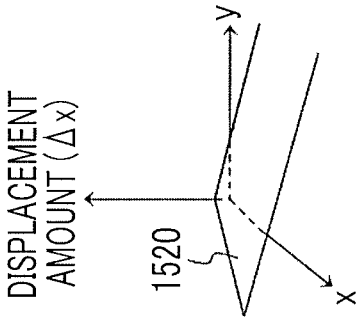


FIG. 15C

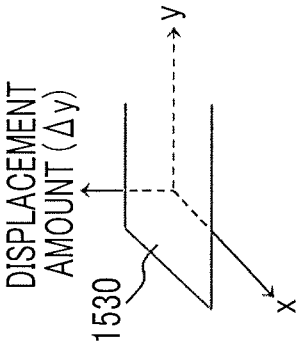


FIG. 16A

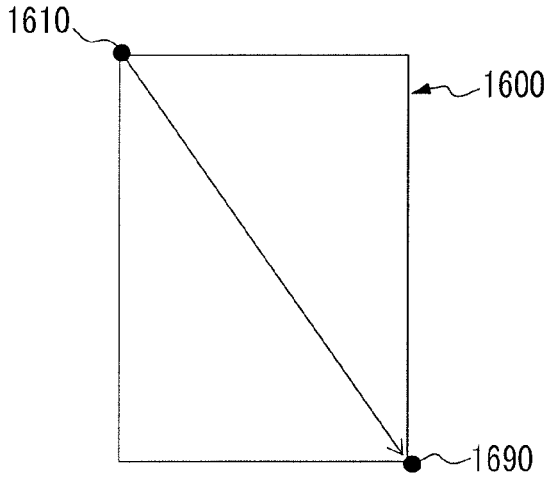


FIG. 16B

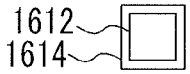


FIG. 16C

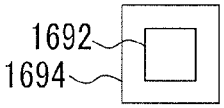


FIG. 17A FIG. 17B FIG. 17C

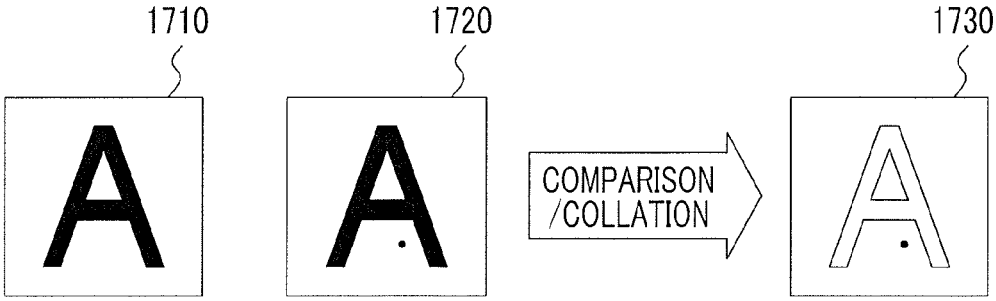


FIG. 18

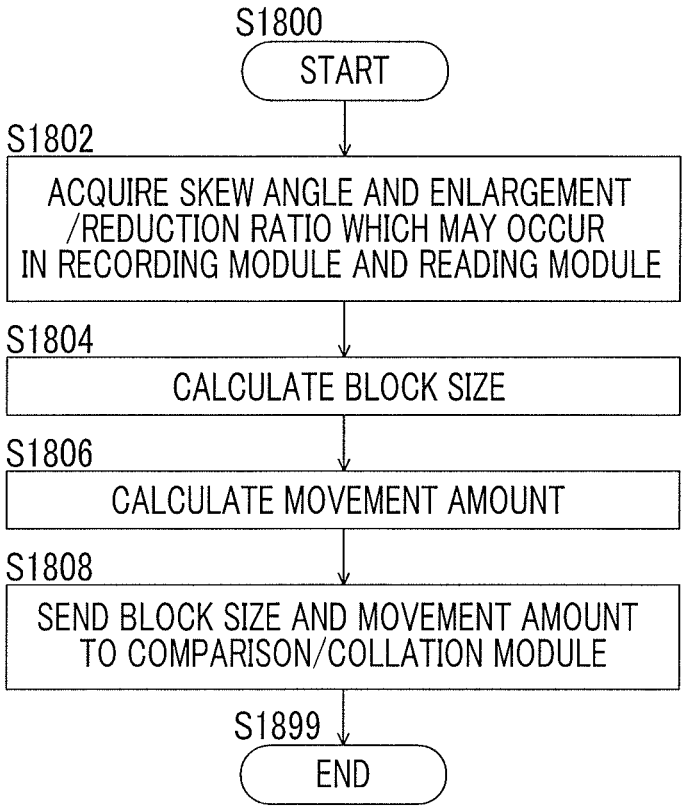


FIG. 19A

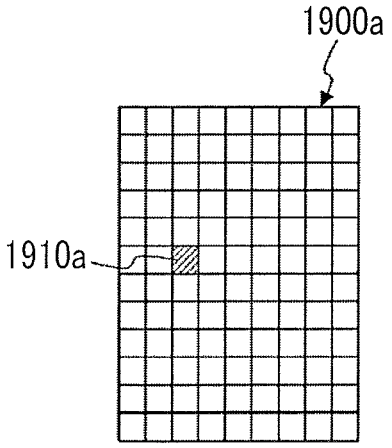


FIG. 19B

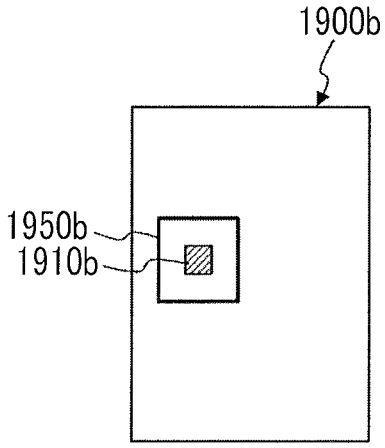


FIG. 20

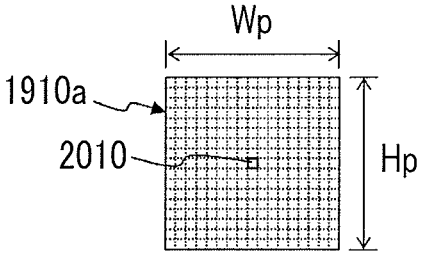


FIG. 21

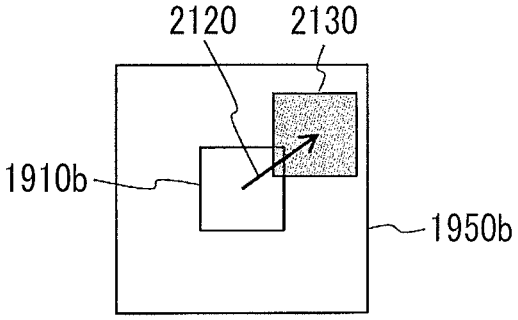


FIG. 22

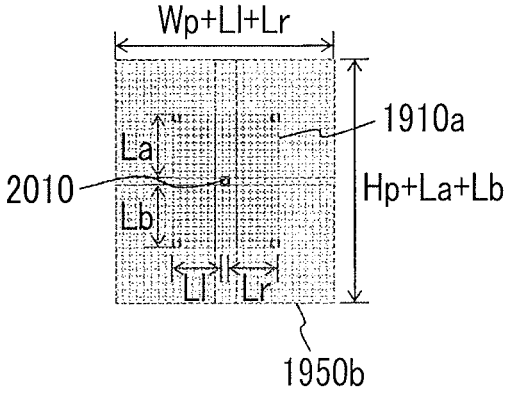


FIG. 23

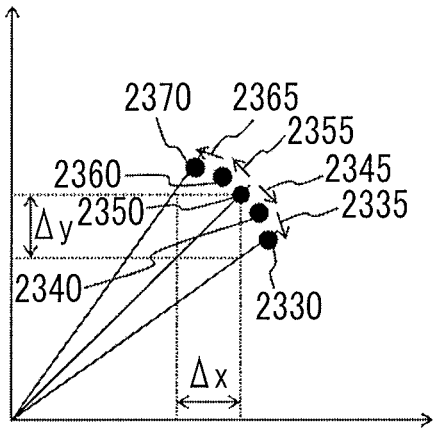

2370
2365
2355
2360
2345
2335
Δy
2350
2340
2330
Δx

FIG. 24

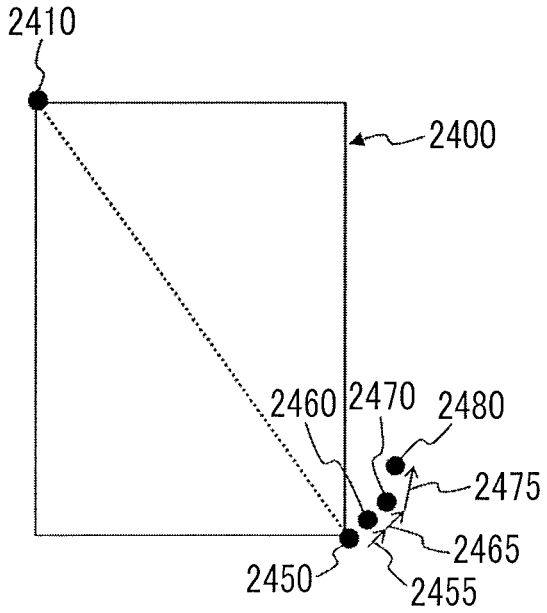

2410
2400
2460
2470
2480
2475
2465
2450
2455

FIG. 25

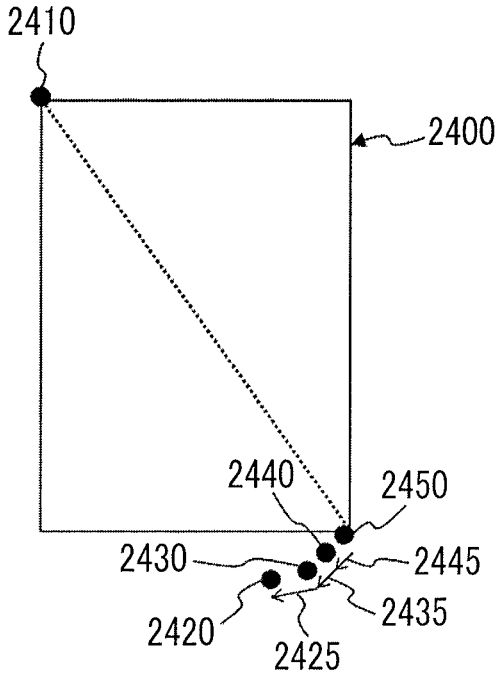


IMAGE PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2014-192403 filed Sep. 22, 2014.

BACKGROUND

Technical Field

The present invention relates to an image processing apparatus.

SUMMARY

According to an aspect of the invention, there is provided an image processing apparatus including:

a correction unit that corrects a tilt of each partial image data item which is a result of plural sensors reading a medium on which an image of image data is formed so that at least part of a reading region which is read by each of the plural sensors overlaps a reading region of an adjacent sensor;

an extraction unit that extracts the image data at a position and in a size at and in which the image data matches the respective partial image data; and

a comparison unit that compares partial image data corrected by the correction unit with extracted image data extracted by the extraction unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention will be described in detail based on the following figures, wherein:

FIG. **1** is a conceptual module configuration diagram illustrating a configuration example according to a first exemplary embodiment;

FIG. **2** is a diagram illustrating a system configuration example in a case where the first exemplary embodiment is realized;

FIG. **3** is a flowchart illustrating a processing example according to the first exemplary embodiment;

FIG. **4** is a diagram illustrating a processing example according to the first exemplary embodiment;

FIG. **5** is a diagram illustrating a processing example according to the first exemplary embodiment;

FIG. **6** is a diagram illustrating a processing example according to the first exemplary embodiment;

FIG. **7** is a diagram illustrating a processing example according to the first exemplary embodiment;

FIG. **8** is a diagram illustrating a processing example according to the first exemplary embodiment;

FIGS. **9**A and **9**B are diagrams illustrating a processing example according to the first exemplary embodiment;

FIG. **10** is a block diagram illustrating a hardware configuration example of a computer which realizes the present exemplary embodiment;

FIG. **11** is a conceptual module configuration diagram illustrating a configuration example according to a second exemplary embodiment;

FIG. **12** is a flowchart illustrating a processing example according to the second exemplary embodiment;

FIGS. **13**A to **13**C are diagrams illustrating a process example in a data collection/position estimation module;

FIG. **14** is a diagram illustrating a process example in the data collection/position estimation module;

FIGS. **15**A to **15**C are diagrams illustrating a process example in the data collection/position estimation module;

FIGS. **16**A to **16**C are diagrams illustrating an example of the size of a search range based on a position in an image;

FIGS. **17**A to **17**C are diagrams illustrating a defect detecting process example;

FIG. **18** is a flowchart illustrating a process example of calculating a block size and a movement amount;

FIGS. **19**A and **19**B are diagrams illustrating a process example according to the second exemplary embodiment;

FIG. **20** is a diagram illustrating a block example;

FIG. **21** a diagram illustrating a process example in a comparison/collation module;

FIG. **22** is a diagram illustrating an example of a relationship between a block image and a search range;

FIG. **23** is a diagram illustrating a process example of calculating a block size;

FIG. **24** is a diagram illustrating a process example of calculating a movement amount; and

FIG. **25** is a diagram illustrating a process example of calculating a movement amount.

DETAILED DESCRIPTION

Hereinafter, exemplary embodiments for implementing the invention will be described with reference to the drawings.

FIG. **1** is a conceptual module configuration diagram illustrating a configuration example according to a first exemplary embodiment.

In addition, the module indicates components such as software (computer program) and hardware which may be generally and logically divided. Therefore, the module in the present exemplary embodiment indicates not only a module in a computer program but also a module in a hardware configuration. Accordingly, the present exemplary embodiment also includes description of a computer program for causing a computer to function as the module (a program for causing a computer to execute the respective procedures, a program for causing a computer to function as the respective units, or a program for causing a computer to realize the respective functions), a system, and a method. For convenience of the description, although the term "store", or "make store", and terms equivalent to these are used, these terms mean that, in a case of a computer program, the program is stored in a storage device or is controlled so as to be stored in the storage device. In addition, the module may correspond to a function in a one-to-one relationship. In a case of mounting, a single module may be configured by a single program, plural modules may be configured by a single program, or conversely a single module may be configured by plural programs. In addition, plural modules may be executed by a single computer, or a single module may be executed by plural computers using computers in distributed or parallel environments. Further, other modules may be included in a single module. Hereinafter, the term "connection" is used not only in a case of physical connection but also in a case of logical connection (data transmission and reception, instruction, reference relationship between data, and the like). The term "predefined" indicates being defined before a process which is a target, and is used to include a meaning of being defined according to circumstances or states at that time or according to circumstances or states hitherto as long as the process which is a target is not performed, even after a process according to the present exemplary embodiment starts

including a state where the process according to the present exemplary embodiment does not start. In a case where there are plural "predefined values", the values may be different, or two or more values (of course, including all the values) may be the same. Further, the phrase having a meaning that "in a case of A, B is performed" is used to mean that "whether or not there is A is determined, if it is determined that there is A, B is performed". However, a case where determination regarding whether or not there is A is unnecessary is excluded.

In addition, the system or the apparatus includes not only a case where plural computers, plural pieces of hardware, plural apparatuses, and the like are configured to be connected to each other via a communication unit such as a network (including communication connection of one-to-one correspondence) but also a case where it is realized by a single computer, a piece of hardware, a single apparatus, and the like. The "apparatus" and the "system" are used as terms having the same meaning. Of course, the "system" does not include social "structures" (social systems) which are merely artificial arrangements.

In addition, for each process performed by each module, or for each process in a case where plural processes are performed in a module, information which is a target is read from a storage device, the process is performed, and then the process result is written in the storage device. Therefore, there are cases where description of reading from the storage device before the process and writing in the storage device after the process may be omitted. The storage device here may include a hard disk, a random access memory (RAM), an external storage medium, a storage device via a communication line, a register in a central processing unit (CPU), or the like.

An image processing apparatus **150** according to a first exemplary embodiment reads image from a recording medium **125** which records the image data thereon and compares the image data with read data, and includes, as illustrated in an example of FIG. **1**, a reading module **160**, a processing module **170**, and a comparison/collation module **180**.

The image processing apparatus **150** receives a printing image **115** from an image recording apparatus **100**, and reads the recording medium **125** printed by the image recording apparatus **100**.

The image recording apparatus **100** includes an image generation module **110** and a recording module **120**. The image recording apparatus **100** and the image processing apparatus **150** may be provided in separate casings, and may be provided in a single casing. The image recording apparatus **100** has a function of an output apparatus such as a printer. The image processing apparatus **150** has a function of an image reading apparatus such as a scanner.

The recording indicates that printing is performed by a printer, for example. The image data is data which is not recorded on the recording medium **125** and indicates an image having no so-called noise (defect). The read data is data which is obtained by the reading module **160** reading an image on the recording medium **125** after the image data is recorded on the recording medium **125**. Therefore, there is a case where noise may occur therein due to a recording process in the recording module **120** and a reading process in the reading module **160**. Here, the noise may include, for example, a case where an image which is not present in image data is recorded on the recording medium **125**, a case where an image which is present in image data is not recorded on the recording medium **125**, and a case where enlargement, reduction, rotation, movement, distortion, or the like occurs in image data.

In the present exemplary embodiment, outputting for determining whether or not noise occurs due to the recording module **120** and the reading module **160** by comparing image data with read data. In a case where noise occurs, the recording module **120** and the reading module **160** are adjusted in order to reduce the noise.

As will be described later, the reading module **160** does not perform general reading in which a single paper sheet is read with a single sensor, but performs reading in which a single paper sheet is read with plural sensors.

The image generation module **110** is connected to the recording module **120** and the processing module **170** of the image processing apparatus **150**, and receives printing data **105** and sends the printing image **115** to the recording module **120** and the processing module **170**. The image generation module **110** converts the printing data **105** into the printing image **115**. Specifically, image conversion processes which are necessary in printing and include a rasterizing process, a conversion process in a color space which may be reproduced by the recording module **120**, and the like, are performed on the printing data **105** in which images such as characters, figures, pictures or the like are described, so that printing may be performed by the recording module **120**. The printing data **105** may be electronic data which is described in, for example, a portable document format (PDF), and may be created by document creation application software, or the like. The printing image **115** may be related to any one of binary image data, grayscale image data, and color image data.

The recording module **120** is connected to the image generation module **110** and the reading module **160** of the image processing apparatus **150**, and receives the printing image **115** from the image generation module **110** and sends the recording medium **125** to the reading module **160**. The recording module **120** records the printing image **115** on a medium such as paper so as to output the recording medium **125**. Specifically, the recording module **120** has a function of a printer. In other words, the printing image **115** is recorded on the recording medium **125**.

The reading module **160** is connected to the recording module **120** of the image recording apparatus **100** and the processing module **170**, and receives the recording medium **125** from the recording module **120** and sends a read image #1:161 . . . and a read image #n:16n to the processing module **170**. The reading module **160** reads the recording medium **125** (a medium on which an image of the printing image **115** is recorded) which is output from the recording module **120**, and generates a read image which is read data. Specifically, the reading module **160** has a function of a scanner. In other words, the printing image on the recording medium **125** is converted into a read image through photoelectric conversion or the like in a reading element. However, as illustrated in an example of FIG. **4**, a single paper sheet is read by plural sensors. In addition, images (partial image data items) read by the respective sensors are sent to the processing module **170** as the read image #1:161 . . . and the read image #n:16n (where n is the number of sensors performing the reading).

FIG. **4** is a diagram illustrating a process example according to the first exemplary embodiment (the reading module **160**). FIG. **4** illustrates that plural sensors **410** read a single paper sheet **450**. The paper sheet **450** is a medium on which an image of image data is formed by the recording module **120**. The sensors **410** are arranged in parallel. A reading range **420***a* is a range of the paper sheet **450** read by a sensor **410***a*. A reading range **420***b* is a range of the paper sheet **450** read by a sensor **410***b*. A reading range **420***c* is a range of the paper sheet **450** read by a sensor **410***c*. A reading range **420***d* is a

range of the paper sheet **450** read by a sensor **410***d*. A reading range **420***e* is a range of the paper sheet **450** read by a sensor **410***e*. In each of the reading ranges **420**, a region including at least one side of the range overlaps a region including at least one side of the adjacent reading range **420**. For example, the right side of the reading range **420***a* overlaps the left side of the reading range **420***b*, and the right side of the reading range **420***b* overlaps the left side of the reading range **420***c*. In other words, the plural sensors perform reading so that at least part of the reading region overlaps the reading region of the adjacent sensor.

In order to prevent omission of reading due to alignment deviations of the sensors **410**, distortions caused by temperature characteristics or the like, or noise such as floating of the paper sheet **450**, typically, reading is performed in a state in which reading regions overlap each other between the adjacent sensors **410**.

FIG. **5** is a diagram illustrating a process example according to the first exemplary embodiment. FIG. **5** illustrates the overlapping of the reading ranges **420** in the paper sheet **450** of the example illustrated in FIG. **4** from the top (or the bottom). An overlapping region **510** is a region in which the reading range **420***a* and the reading range **420***b* overlap each other. An overlapping region **512** is a region in which the reading range **420***b* and the reading range **420***c* overlap each other. An overlapping region **514** is a region in which the reading range **420***c* and the reading range **420***d* overlap each other. An overlapping region **516** is a region in which the reading range **420***d* and the reading range **420***e* overlap each other. Here, the term "overlap each other" indicates that two sensors read a portion of the same medium. For example, the overlapping region **512** is read by both the sensor **410***b* and the sensor **41***c*.

The processing module **170** is connected to the image generation module **110** of the image recording apparatus **100**, the reading module **160**, and the comparison/collation module **180**, and receives the printing image **115** from the image generation module **110** and the read image #1:161 . . . and the read image #n:16n from the reading module **160**, and sends a printing image **172** and a read image **174** to the comparison/collation module **180**. The processing module **170** corrects a tilt of partial image data. The correction of a tilt may be performed by using an existing technique. For example, a line segment in the partial image data may be extracted, and may be rotated in a reverse direction after an angle between the line segment and a vertical line or a horizontal line is detected. In addition, a tilt may be detected based on a tilt of a side (paper edge) of the recording medium **125**. Further, a tilt of partial image data may be corrected based on an angle detected in each partial image data item, and tilts of other partial image data items may be corrected based on an angle detected in any one of partial image data items. The tilt correction may be performed by using, specifically, affine transform.

In addition, the processing module **170** extracts an image from the printing image **115** which is image data, so as to be suitable for positions and sizes of the read image #1:161 and the like. Here, the image is extracted at the same tilt as the tilt of the partial image data. Therefore, at least one side of extracted image data which is an extraction result of the printing image **115** overlaps a region including one side of adjacent extracted image data, in the same manner as in the read image #1:161 and the like.

The processing module **170** may receive the printing image **115** not only from the image generation module **110**, but also from an information processing apparatus (an information processing apparatus which sends the printing data **105** to the image recording apparatus **100**) which generates the printing data **105**, from the recording module **120**, and from the reading module **160** in a case where the reading module **160** receives the printing image **115** from the image generation module **110** or the recording module **120**.

Further, the processing module **170** may insert a blank space between the partial image data items adjacent to each other of the read image #1:161 and the like so as to correct a tilt, and then may combine the partial image data items with each other so as to generate combined image data. Here, the blank space may have any color (white, black, transparent or the like) and is a region having a fixed value. In addition, the blank space may be a region which is set not to be output as a difference even if the region is compared. In other words, in a case where blank spaces are compared with each other, a region in which it is determined that there is no difference is used as a blank space. In addition, a width of this blank space is equal to or larger than a width of the region in which at least the partial image data items overlap each other. Further, a width of the blank space may be determined in consideration of a tilt angle of the partial image data. In other words, even if a tilt angle is corrected, a width of the blank space is determined so that the overlapping of the partial image data in the longitudinal direction is removed. Consequently, during comparison and collation in the comparison/collation module **180** which will be described later, it is possible to specify in which read image (sensor) a different portion is generated only by referring to coordinates of a comparison result in the width direction. Still further, a width of the blank space may be a width corresponding to a size of a comparison target (block) in the comparison/collation module **180**. For example, a multiple of a horizontal width of the comparison target (block) may be used. A blank space may be inserted between extracted image data items which are obtained by dividing the printing image **115** and are adjacent to each other. In this case, the blank space inserted into the extracted image data may be compared in the same condition as in the combined image data when a width thereof is set to a width of a blank space which is inserted into partial image data and is obtained by correcting a tilt.

The comparison/collation module **180** is connected to the processing module **170**, and receives the printing image **172** and the read image **174** from the processing module **170** so as to output a collation result **185**. The comparison/collation module **180** compares the partial image data (read image #1:161 and the like) corrected by the processing module **170** with the extracted image data (extracted image data of the printing image **115**) extracted by the processing module **170**. Comparison targets here are the partial image data (the read image #1:161 and the like) of which a tilt is corrected and the extracted image data of the printing image **115**.

The comparison/collation module **180** compares the combined image data (combined image data based on the read image #1:161 and the like) generated by the processing module **170** with the image data in which a blank space is inserted between the extracted image data items of the printing image **115**. Comparison targets here are a combination of the partial image data items (the read image #1:161 and the like) of which tilts have been corrected, and a combination of extracted image data items of the printing image **115**.

The comparison is a process of detecting a difference between both images. For example, an exclusive OR (EOR) process of both images may be performed, and a difference between both of the images may be extracted, and a portion having values other than 0 is detected as a different portion. In addition, there is a process of extracting an image which is present in the printing image **172** but is not present in the read image **174**, a process of extracting an image which is not

present in the printing image **172** but is present in the read image **174**, and the like. It is determined that noise occurs in the different portion.

Here, the outputting of the collation result **185** includes, for example, printing the different portion with a printing apparatus such as a printer, displaying the different portion on a display apparatus such as a display, transmitting an image with an image transmission apparatus such as a facsimile, writing an image in an image storage apparatus such as an image database, storing an image on a recording medium such as a memory card, and sending an image to other information processing apparatuses.

FIG. **2** is a diagram illustrating a system configuration example in a case where the first exemplary embodiment is realized.

The image recording apparatus **100**, the image processing apparatus **150**, a printing data generation apparatus **210**, and a collation result storage apparatus **220** are connected to each other via a communication line **290**. The communication line **290** may be a wired line, a wireless line, and a combination thereof, and may be, for example, the Internet as a communication infrastructure. The printing data generation apparatus **210** generates the printing data **105**, and sends the printing data **105** to the image recording apparatus **100**. The image recording apparatus **100** prints the printing data **105** and outputs the recording medium **125**. The image processing apparatus **150** reads the recording medium **125**, and receives the printing data **105** from the image recording apparatus **100** (or the printing data generation apparatus **210**) and sends the collation result **185** to the collation result storage apparatus **220**. The collation result storage apparatus **220** receives and stores the collation result **185** from the image processing apparatus **150**. The recording module **120** of the image recording apparatus **100** and the reading module **160** of the image processing apparatus **150** are adjusted based on the collation result **185** stored in the collation result storage apparatus **220**.

FIG. **3** is a flowchart illustrating a process example according to the first exemplary embodiment.

In step S**302**, the image generation module **110** performs image conversion of the printing data **105** so as to generate the printing image **115**.

In step S**304**, the recording module **120** records the printing image **115** on a medium. The recording medium **125** on which the printing image **115** is printed is generated.

In step S**306**, the reading module **160** reads the recording medium **125**.

FIG. **6** is a diagram illustrating a process example according to the first exemplary embodiment. An image **600** indicates an image right after reading is performed. The image **600** is formed by images (read divided images **610**, **612**, **614**, **616** and **618**) read by the respective sensors **410**, and includes overlapping regions **510**, **512**, **514** and **516** as overlapping portions. In addition, the overlapping region **510** displays image data items which are respectively read by the sensor **410***a* and the sensor **410***b* in an overlapping manner. Therefore, there is a possibility that there may be a difference between a portion of the overlapping region **510** read by the sensor **410***a* and a portion of the overlapping region **510** read by the sensor **410***b*.

In step S**308**, the processing module **170** detects skew angles of the read image #1:161 and the like. For example, a skew angle is detected based on a tilt of a paper edge of the read image.

In step S**310**, the processing module **170** performs processing on the read image #1:161 . . . and the read image #n:16n, and the printing image **115**. As the processing here, a blank space is inserted between the divided read image in accordance with, for example, the skew angle, and a size (block size) of a comparison target in collation performed by the comparison/collation module **180**.

FIG. **7** is a diagram illustrating a process example according to the first exemplary embodiment. An image **700** indicates an image state in which blank spaces are inserted into the image **600** illustrated in the example of FIG. **6**. In other words, a blank space **710** is inserted between the read divided image **610** and the read divided image **612**; a blank space **712** is inserted between the read divided image **612** and the read divided image **614**; a blank space **714** is inserted between the read divided image **614** and the read divided image **616**; and a blank space **716** is inserted between the read divided image **616** and the read divided image **618**. In addition, the read divided image **612** includes the overlapping region **510** and the overlapping region **512** read by the sensor **410***b*.

FIG. **8** is a diagram illustrating a process example according to the first exemplary embodiment. An image **800** indicates an image state in which skew correction is performed on the image **700** illustrated in the example of FIG. **7**. In other words, the state is a state in which the tilts of the read divided image **612** and the like are removed. A tilt of any one of the read divided images **610**, **612**, **614**, **616** and **618** may be detected as the tilt here, and the read divided images **610**, **612**, **614**, **616** and **618** may be corrected according to the tilt, and a tilt of each of the read divided images **610**, **612**, **614**, **616** and **618** may be detected, and the read divided images **610**, **612**, **614**, **616** and **618** may be corrected in accordance with each tilt.

FIGS. **9**A and **9**B are diagrams illustrating a process example according to the first exemplary embodiment. An image **900** illustrated in an example of FIG. **9**A is obtained by performing size correction suitable for a processed output image **950**, on the image **800** illustrated in the example of FIG. **8**. The size correction here indicates that a bottom side portion (or a top side portion) of the image **800** is removed, and a right side portion (or a left side portion) thereof is removed, in order to generate the same size as the size of the processed output image **950**. The processed output image **950** illustrated in an example of FIG. **9**B is obtained by extracting the image from the printing data **105** and inserting blank spaces thereinto. In addition, in the extraction process, images having the same sizes as those of the read image #1:161 and the like are extracted. However, an overlapping region is made to be included in both divided images adjacent to each other. Further, blank spaces (blank spaces **970**, **972**, **974** and **976**) having the same sizes (horizontal widths) as the sizes (horizontal widths) after the skew correction is performed, illustrated in the example of FIG. **7**, are inserted between the respective divided images (output divided images **960**, **962**, **964**, **966** and **968**).

In step S**312**, the comparison/collation module **180** compares and collates the printing image **172** and the read image **174** which are converted images, with each other, so as to detect a defect occurrence region.

Here, the defect detection may be performed as follows.

1) At least one of the printing image **172** and the read image **174** is divided so that plural block images are extracted, and a difference absolute value of both of the images is calculated for each pixel on an image different from the image from which the block images are extracted while changing a position of the block image in a predefined search range between the printing image **172** and the read image **174**.

2) A position where a sum of the difference absolute values is the minimum is searched for in the block, and a difference image is generated.

3) A defect is detected from the difference image. For example, a portion in which a pixel value of the difference image is greater than, or equal to or greater than a predefined threshold value, is detected as a result thereof.

In step S**314**, the collation result **185** is output.

The process in step S**312** will be described in detail by using a second exemplary embodiment. The comparison/collation module **180** performs processes of a data collection/position estimation module **1140**, a block movement amount calculation module **1150**, and a comparison/collation module **1160** described in the following example. The same portions as in the above-described exemplary embodiment are given the same reference numerals, and repeated description will be omitted. A reading module **1130** corresponds to the reading module **160**. In addition, the printing image **115** corresponds to the printing image **172**, and a read image **1135** corresponds to the read image **174**. In other words, the comparison/collation module **180** in the first exemplary embodiment performs a process equivalent to the process on the printing image **115** and the read image **1135** in the second exemplary embodiment, since each of the printing image **172** and the read image **174** is processed as a single image.

The entire image processing system including an image processing apparatus according to the second exemplary embodiment compares image data with read data, and includes the image recording apparatus **100** and an image processing apparatus **1170** as illustrated in an example of FIG. **11**. The image recording apparatus **100** includes the image generation module **110** and the recording module **120**, and the image processing apparatus **1170** includes the reading module **1130**, the data collection/position estimation module **1140**, the block movement amount calculation module **1150**, and the comparison/collation module **1160**.

The reading module **1130** is connected to the data collection/position estimation module **1140** and the comparison/collation module **1160**. The reading module **1130** converts the printing image **115** on the recording medium **125** into the read image **1135** using photoelectric conversion or the like. In other words, the read image **1135** which obtained by reading the recording medium **125** is generated. This is a so-called scanning process, and the reading module **1130** is implemented by a scanner which is an image reading device. The read image **1135** is sent to the data collection/position estimation module **1140** and the comparison/collation module **1160**.

The data collection/position estimation module **1140** is connected to the image generation module **110**, the reading module **1130**, the block movement amount calculation module **1150**, and the comparison/collation module **1160**. The data collection/position estimation module **1140** sets a search range which is calculated based on an error, and searches for a position which a selected block image matches in one of the printing image **115** and the read image **1135** in relation to a block image extracted from the other. The searched position (an estimated value **1145** of a displacement amount) is sent to the comparison/collation module **1160**. The comparison/collation module **1160** compares and collates the block image with the other image by overlapping the two images at the searched position, so as to detect a defect occurrence region.

A position estimation of a block image in the data collection/position estimation module **1140** may be performed as follows without first performing position search regarding all block images.

First, a search process will be described. This process shows an example of the process in step S**312** according to the first exemplary embodiment. Description thereof will be made with reference to FIG. **21**. FIG. **21** is a diagram illustrating a process example in the comparison/collation module **1160**. A block image **1910***a* of a reference image **1900***a* is shifted by one pixel in a search range **1950***b* of a read image **1900***b*, so that template matching (for example, an EOR process) is performed. In addition, as a result of the template matching, a relative position to a block image in which the maximum score (for example, as a score, an inverse number of a difference absolute value) indicating the most proximity in the search range **1950***b* is set as a displacement amount **2120**. In other words, one in the block image **1910***b* corresponding to the block image **1910***a* is a block image **1901***b*, and in a case where a block image **2130** is extracted at the maximum score position as a result of performing template matching between the block image in the search range **1950***b* and the block image **1910***a*, the displacement amount **2120** is set. In addition, the comparison/collation module **1160** receives the estimated value **1145** of the displacement amount from the data collection/position estimation module **1140**, and searches for a target block. Further, estimation of a plane is not necessarily performed in the template matching (of course, as will be described later, a plane estimation process may be performed for the template matching).

Hereinafter, a detailed description of a process example according to the second exemplary embodiment will be described.

The data collection/position estimation module **1140** selects at least one of block images extracted from one of the printing image **115** and the read image **1135**, sets a search range calculated based on an error, and searches for a position which the selected block image matches in other image. Then, a corresponding position of an unselected block image in the other image is estimated based on the corresponding position of the selected block image matching in the other image. In addition, the estimated position (the estimated value **1145** of the displacement amount) is sent to the comparison/collation module **1160**.

First, with reference to FIGS. **13**A to **14**, a description will be made of a process of estimating a corresponding position of a block image in the other image. FIGS. **13**A to **13**C are diagrams illustrating a process example in the data collection/position estimation module **1140**.

1) As illustrated in examples of FIGS. **13**A and **13**B, the printing image **115** and the read image **1135** are respectively divided into rectangular shapes (hereinafter, referred to as blocks), so as to generate a printing block image **1310** and a read block image **1320**. In other words, images of the printing image **115** and the read image **1135** are divided into blocks which are generated based on errors which may occur in the recording module **120** or the reading module **1130**, and thus block images are extracted. In addition, as a block size here, a block size **1152** which is calculated by the block movement amount calculation module **1150** is used.

More specifically, the following process is performed.

One of the printing image **115** and the read image **1135** is divided into a rectangular shape which is generated based on errors which may occur in the recording module **120** or the reading module **1130**, and thus a rectangular image is extracted. One image may be the printing image **115** or the read image **1135**. Hereinafter, a description will be mainly made assuming that the printing image **115** is used as one image, and the read image **1135** is used as the other image. The block division will be described with reference to FIGS. **19**A and **19**B. FIGS. **19**A and **19**B are diagrams illustrating a process example according to the second exemplary embodiment. In the example of FIG. **19**A, the reference image **1900***a* is divided into 9×12 blocks. Of course, a division number differ depending on a block size and a size of the reference

image **1900***a*. In addition, the division number is not necessarily an integer number depending on a relationship between the block size and the size of the reference image **1900***a*, and a white image or the like may be added to a portion which does not form a single block. Further, the block division is performed based on the block size **1152** received from the block movement amount calculation module **1150**.

FIG. **20** is a diagram illustrating a block example, and enlarges and displays the block image **1910***a* illustrated in the example of FIG. **19**A. The block image **1910***a* has a size of Wp×Hp. In addition, coordinates of a central pixel **2010** of the block image **1910***a* are set to (Cx,Cy).

2) As illustrated in the example of FIG. **13**C, at least one set of extracted block images is selected, and a difference absolute value of both of the images is calculated for each pixel in blocks (the printing image **115** and the read image **1135**) at a corresponding position. For example, an exclusive OR (EOR) process may be performed for each pixel.

3) A position where a sum of the difference absolute values (a sum total of the difference absolute values in the respective pixels in the block) in the block is the minimum is searched for. In addition, a search range A here may or not be the same as the estimated value **1145** of the displacement amount used in the comparison/collation module **1160**. The search range may be defined based on a movement amount **1154** calculated by the block movement amount calculation module **1150**, and may be a search range which will be described later with reference to FIGS. **16**A to **16**C.

In the examples of FIGS. **13**A to **13**C, the printing block image **1310** is searched for in the read block image **1320**. In other words, the printing block image **1310** and the read block image **1320** are shift in the search range A, and a sum of the difference absolute values in a positional relationship thereof is calculated. A positional relationship between rectangular images in which the calculated sum of the difference absolute values is the minimum is specified. As illustrated in an example of FIG. **14**, a printing block image **1410** is searched for regarding a read block image **1420** in a read image **1400**. A position **1450** where a sum of the difference absolute values is the minimum is obtained in the search range A. The position **1450** corresponds to, for example, differences (Δx,Δy) between central coordinates of the printing block image **1410** and the read block image **1420**. Here, an example has been described in which the printing block image **1310** is searched for in the read block image **1320**, but the read block image **1320** may be searched for in the printing block image **1310**. In the present exemplary embodiment, both the printing image and the read image are cut out as blocks, but only the printing image may be cut out as a block image, a search range may be directly set in the other read image, and a position where a sum of difference absolute values is the minimum may be searched for in a range thereof in the same manner. In addition, only the read image may be cut out as a block image, a search range may be directly set in the other printing image, and a position where a sum of difference absolute values is the minimum may be searched for in a range thereof in the same manner.

In the present exemplary embodiment, the search range A is calculated as follows.

A range of a movement amount for defining the search range A is determined based on errors which may occur in the recording module **120** which forms an image of the printing image **115** on the recording medium **125** or the reading module **1130** which reads the recording medium **125**, and an image (which may be either the printing image **115** or the read image **1135**). The "errors which may occur in the recording module **120** or the reading module **1130**" will be described later in description of the block movement amount calculation module **1150**. For example, the data collection/position estimation module **1140** increases a movement amount according to a distance from an origin in the printing image **115** or the read image **1135**, and calculates a movement amount at the most distant point from the origin so that a movement amount having undergone affine transform which is an error which may occur in the recording module **120** or the reading module **1130** becomes the maximum in a size of the printing image **115** or the read image **1135**. The distance from the origin is the same value as a value of a position of the block. The origin of the printing image **115** or the read image **1135** is a position where the occurrence of an error in the recording module **120** or the reading module **1130** is the minimum, and indicates, for example, coordinates of an upper left corner of the image. The "most distant point from the origin" is a position which is the most distant from the origin. The position which is the most distant from the origin is a position where the occurrence of an error in the recording module **120** or the reading module **1130** is the maximum, and indicates, for example, coordinates of a lower right corner of the image. Specifically, the data collection/position estimation module **1140** increases a size of the search range A in a direction from the coordinates of the upper left corner to the lower right corner. The maximum size thereof is defined based on the maximum value of an "error which may occur in the recording module **120** or the reading module **1130**", and is a movement amount **1154** calculated by the block movement amount calculation module **1150**.

A description thereof will be made by using an example of FIGS. **16**A to **16**C. FIGS. **16**A to **16**C are diagrams illustrating an example of a size of the search range A based on a position inside an image. FIG. **16**A illustrates an example of positions of an origin **1610** (upper left corner) of an image **1600** and the most distant point **1690** (lower right corner). In addition, FIG. **16**B illustrates an example of a relationship between a block **1612** and a search range A **1614** at the origin **1610**. The search range A **1614** is larger than the block **1612** by a predefined value (0 or greater). FIG. **16**C illustrates an example of a relationship between a block **1692** and a search range A **1694** at the most distant point **1690**. The search range A **1694** has a size defined based on the movement amount **1154** calculated by the block movement amount calculation module **1150**. Further, sizes of the block **1612** and the block **1692** are the same as each other, and are the block size **1152** calculated by the block movement amount calculation module **1150**. Here, an example in which the upper left corner is set as the origin, and the lower right corner is set as the most distant point, but any one of four points (the lower right corner, the upper right corner, the lower left corner, and the upper left corner) may be used depending on properties of errors which may occur in the recording module **120** or the reading module **1130**. Here, as the examples, cases have been described in which rotation of the recording module **120** or the reading module **1130** occurs centering on the upper left corner, and an effect of enlargement or reduction becomes greater as a point becomes farther from the upper left corner.

Next, the data collection/position estimation module **1140** searches for a corresponding position of the extracted rectangular image in the other image in the search range A, by using the position **1450** at which the sum of the difference absolute values is the minimum in the search range A as a reference. For example, FIG. **19**B illustrates an example of searching for the block image **1910***a* illustrated in FIG. **19**A. As illustrated in FIG. **19**B, the block image **1910***a* is searched for in the search range **1950***b* which is a "range of a movement amount" inside the read image **1900***b*. In addition, one corresponding

to the block image **1910***a* in the reference image **1900***a* is a block image **1910***b* in the read image **1900***b*. Ideally (in a case where errors which may occur in the recording module **120** and the reading module **1130** are 0), in order to detect a defect, the block image **1910***a* and the block image **1910***b* have only to be compared with each other, but, actually, since errors occur in the recording module **120** and the reading module **1130**, the search is made in the search range **1950***b* (a search range determined by the data collection/position estimation module **1140**) which is determined in consideration of the actual errors. Consequently, the entire read image **1900***b* is not required to be searched for, and a position which matches the block image **1910***a* in the read image **1900***b* may be found. The search range is a region which includes a rectangular shape of the other image at the same position as the rectangular position in one image and is formed by vertical and horizontal movement amounts with respect to the rectangular shape.

The search process is as described with reference to FIG. **21**. The example illustrated in FIG. **21** displays the search range **1950***b* illustrated in the example of FIG. **19**B in an enlarged manner.

A block in which there may be plural positions where a sum of difference absolute values is the minimum is excluded in advance as a source for estimating positions of unselected other blocks described later.

For example, there are a block (which may include a case where a whole pixel value difference is equal to or smaller than a predefined value even if the block is painted with exactly the same color) which is painted with the same color (for example, white, black, or transparent) as a whole, a block in which only a single straight line is drawn, a block in which only plural parallel lines are drawn, and a block in which plural regular graphics (substantially the same graphics) are drawn. Since it is not possible to uniquely determine a corresponding position in these blocks, it is not possible to estimate a position of an unselected block, or even if a position may be estimated, an error may increase, and thus the blocks are not suitable for estimating a position.

The time at which it is determined that these blocks are excluded may be when a block is selected, and may be when a position of another image is estimated after a block is selected and then a corresponding position is searched, but if the blocks are excluded when a block is selected, it is possible to reduce a calculation amount required for an unnecessary search.

In a case where a distance between rectangular images in which a sum of difference absolute values is the minimum is greater than or equal to a predefined value as a result in which a block is selected and a search is made, a positional relationship between the blocks is excluded as a source for estimating positions of unselected other blocks.

Next, a description will be made of estimation of a corresponding position of a block image which is not selected by the data collection/position estimation module **1140** in the other image, with reference to FIGS. **15**A to **15**C. FIGS. **15**A to **15**C are diagrams illustrating a process example in the data collection/position estimation module **1140**. As illustrated in an example of FIG. **15**A, a position where a sum of difference absolute values is the minimum in blocks (blocks with the diagonal lines in FIG. **15**A) of a printing image **1510** is calculated. In addition, excluded blocks (white blocks in FIG. **15**A) are not used for a position estimation process. The data collection/position estimation module **1140** calculates a plane (which may be a "plane in a characteristic space") defined by a position between block images, and estimates positions of unselected block images based on the plane. Specifically, a plane indicating a displacement amount is calculated from the position where the sum of difference absolute values is the minimum, and a displacement amount is calculated according to a position of each block.

In other words, the following process is performed. A position $(\Delta x,\Delta y)$ of the block image is plotted in the characteristic space. As the characteristic space, for example, there is a three-dimensional space which has an x axis, a y axis, and Δx or Δy as an axis. Here, the x axis and the y axis are axes representing coordinates of a center of the block. The characteristic space may be a four-dimensional space which has an x axis, a y axis, a Δx axis, and a Δy axis, and may be other spaces as long as an axis representing Δx or Δy is included. A plane formed through the plotting is calculated. For example, the plane is a plane **1520** representing a displacement amount (Δx) in the example of FIG. **15**A, and is a plane **1530** representing a displacement amount (Δy) in the example of FIG. **15**B. Of course, all positions are not required to be plotted in a plane, and a plane estimated through the plotting may be calculated by using an existing method.

It is possible to estimate displacement amounts in all blocks in an image by using the plane representing the displacement amounts. Specifically, a position of each block is assigned to an equation $(\Delta x=a_1x+b_1y+c_1,\ \Delta y=a_2x+b_2y+c_2)$ representing the plane, and a displacement amount in each block is estimated.

In relation to estimation of a displacement amount here, at least an unselected block image is required to be targeted. In a case where this process is sequentially performed, when only an unselected block image is targeted, a calculation amount of the displacement amount estimation is further reduced than when all block images are targeted, and thus the process may be performed at a high speed. In a case where the displacement amount estimation is performed in parallel processes by using a multicore CPU, GPU or the like, the process may be performed at a higher speed when the process is uniformly applied to all block images than when a step of determining whether or not a block image is a selection target is added.

Next, the data collection/position estimation module **1140** searches for a corresponding position in the other image for each block image based on the displacement amount estimated by using the above-described method. In other words, a search range is set by using the estimated displacement amount as a reference position, template matching is performed, and a position indicating the most proximity in the search range is searched for. The template matching here may employ the same method as the above-described template matching.

A search target here is at least an unselected block image. In a case where this process is sequentially performed, when only an unselected block image is targeted, a calculation amount of the displacement amount estimation is further reduced than when all block images are targeted, and thus the process may be performed at a high speed. In a case where the second position search is performed in parallel processes by using a multicore CPU, GPU or the like, the process may be performed at a higher speed when the process is uniformly applied to all block images than when a step of determining whether or not a block image is a selection target is added.

The search range here may be determined in the same manner as in the above-described method of determining a search range, but a position has already been estimated for an unselected block image, and thus a range smaller than that may be set as the search range. A calculation amount required for difference extraction is further reduced than in a case of using the same search range.

The comparison/collation module **1160** is connected to the image generation module **110**, the reading module **1130**, and the data collection/position estimation module **1140**. The comparison/collation module **1160** compares and collates the printing image **115** with the read image **1135** so as to detect the presence or absence of a defect and a defect occurrence region. The comparison/collation module **1160** receives the printing image **115** and the read image **1135**. The read image **1135** reads the recording medium **125** on which an image of the printing image **115** is formed. In other words, the comparison/collation module **1160** receives the printing image **115** which is a source of a print-out target, and the read image **1135** which is obtained by printing out the printing image **115** and scanning the printed-out recording medium **125**. This is because the presence or absence of a defect which occurs in the recording module **120** or the reading module **1130** is checked. Here, the defect indicates noise, and, ideally, the printing image **115** completely matches the read image **1135**. However, a defect occurs due to maintenance statuses of the recording module **120** and the reading module **1130**. In addition, an error may occur in the recording module **120** and the reading module **1130**. Here, the "error which may occur" is an error which is allowable in design specifications of the recording module **120** and the reading module **1130**. As the error, specifically, there are enlargement or reduction, rotation, and affine transform of movement. In a case where a design specification is realized (a design goal is achieved) in which, for example, rotation of x degrees or larger does not occur, rotation of below x degrees may occur.

Therefore, the comparison/collation module **1160** extracts a defect (for example, a mixture of three or more black pixels) from which an error which may occur in the recording module **120** and the reading module **1130** is excluded. In other words, it is checked whether or not a defect other than an allowable error in the design specification, and a position where the defect occurs is specified to be usefully used for maintenance of the recording module **120** and the reading module **1130**.

Next, the comparison/collation module **1160** receives a search result from the data collection/position estimation module **1140**, and compares an extracted rectangular image with an image (an image of the search result) of a portion to which the extracted rectangular image corresponds in the other image. In other words, both of the images overlap each other at a position where the rectangular image of the printing image side and the rectangular image of the read image side match each other most, and comparison for extracting a difference therebetween is performed. The "search result" is a result in which a position where both of the images match each other most is extracted by comparing the rectangular image in one image within a search range of the other image. The difference between the position and the position of the rectangular image may be used as a displacement amount. The search result may be used for the "comparison". In other words, the search result is obtained in a case where the most matching occurs, and thus a matching degree may be used as a defect detection result **1165**. In addition, the defect detection result **1165** may include not only the matching degree but also a displacement amount.

A description thereof will be made with reference to FIGS. **17**A to **17**C. FIGS. **17**A to **17**C are diagrams illustrating a defect detection process example in the comparison/collation module **1160**. A printing block image **1710** illustrated in an example of FIG. **17**A is a block image in the printing image **115**; a read block image **1720** illustrated in an example of FIG. **17**B is a block image in the read image **1135**; and a difference block image **1730** illustrated in an example of in FIG. **17**C indicates a difference (a result of an EOR process) between the printing block image **1710** and the read block image **1720**. The comparison/collation module **1160** generates a difference image for each block, and detects a defect in the difference image. As the defect, for example, a defect may be detected in which a size of one side of a circumscribed rectangle is a size within a predefined range (for example, three pixels to five pixels).

The block movement amount calculation module **1150** is connected to the data collection/position estimation module **1140**. The block movement amount calculation module **1150** calculates the block size **1152** and the movement amount **1154** based on the error which may occur in the recording module **120** or the reading module **1130**. The block size **1152** and the movement amount **1154** are sent to the data collection/position estimation module **1140**. The error in the recording module **120** or the reading module **1130** includes affine transform in the image forming apparatus or the image reading apparatus. Specific examples of the error include an enlargement or reduction ratio or a rotation angle. The process in the block movement amount calculation module **1150** may be performed before the data collection/position estimation module **1140** performs a process, and the block size **1152** and the movement amount **1154** may be calculated in advance and be stored in the data collection/position estimation module **1140**. Further, in order to correspond to the recording module **120** and the reading module **1130** used at that time, the block size **1152** and the movement amount **1154** may be calculated whenever errors are received from the recording module **120** and the reading module **1130**.

The block size **1152** is defined through affine transform so that a pixel deviation between a rectangular image of one image and a rectangular image of the other image is smaller than one pixel. In addition, calculation of the block size **1152** will be described later by using an example of FIG. **23**.

The movement amount **1154** calculated by the block movement amount calculation module **1150** is defined so that a movement amount obtained by affine transform is the maximum in a size of the printing image **115** or the read image **1135**. The movement amount **1154** is used to form the search range **1950***b*.

FIG. **22** is a diagram illustrating a relationship example between the block image **1910***a* and the search range **1950***b*. The movement amount **1154** includes, specifically, an upward movement amount, a downward movement amount, a left movement amount, and a right movement amount.

A height (block height) of the block image **1910***a* is L_a+1+L_b, and is H_p illustrated in the example of FIG. **20**.

A width (block width) of the block image **1910***a* is L_1+1+L_r, and is W_p illustrated in the example of FIG. **20**.

A height (search range height) of the search range **1950***b* is $H_p+L_a+L_b$. L_a indicates an upward movement amount. L_b indicates a downward movement amount.

A width (search range width) of the search range **1950***b* is $W_p+L_1+L_r$. L_1 indicates a left movement amount. L_r indicates a right movement amount.

In addition, calculation of the movement amount **1154** will be described later by using examples of FIGS. **24** and **25**.

The movement amount **1154** indicates the maximum value of a search range in the image, and the data collection/position estimation module **1140** determines the estimated value **1145** of a displacement amount based on a position of the block in the image by using the movement amount **1154**.

All process examples according to the second exemplary embodiment will be described.

First, the image generation module **110** performs image conversion on the printing data **105** so as to generate the printing image **115**.

Next, the recording module **120** records the printing image **115** on the recording medium **125**.

Next, the reading module **1130** reads the recording medium **125** on which the printing image **115** is recorded. The read result is the read image **1135**.

Next, the data collection/position estimation module **1140** collects data items (specifically, differences between block images) for determining the estimated value **1145** of a displacement amount.

Next, the data collection/position estimation module **1140** estimates a displacement amount for each block.

Next, the comparison/collation module **1160** compares and collates the converted image (printing image **115**) with the read image **1135** so as to detect a defect occurrence region.

FIG. **12** is a flowchart illustrating a process example according to the second exemplary embodiment.

In step S**1202**, at least one of a printing data image and a read data image is divided. As a division method here, the image is divided in a size which is calculated by using an error (for example, the size becomes smaller as the error increases).

In step S**1204**, a search range is determined in some divided images. The determination of the search range here is performed in a size which is calculated by using an error (for example, the size becomes larger as the error increases).

In step S**1206**, a corresponding position in a partner image is specified. Specifically, the divided image overlaps the other image so that a difference is obtained for each pixel, absolute values of differences are added together while changing a position of the image in the search range, and a position where the difference is smallest is set as a corresponding position.

In step S**1208**, a corresponding position of another divided image in the partner image is estimated based on specified corresponding position. Specifically, a deviation amount between the corresponding position and an initial position is plotted in a plane, and a deviation amount of another divided image is estimated based on the plane and a position relative to the division source image of the divided image.

In step S**1210**, a corresponding position of another divided image in the partner image is specified based on the estimated position. A search range here may be the same as the search range in step S**1204**, but may be a second search range narrower than the search range determined in step S**1204**. This is because the searched divided image here is searched for from the position estimated in step S**1208**, and thus a corresponding position is located nearby. The second search range is applied, and thus a calculation amount which requires differences for specifying a position is reduced.

In step S**1212**, a comparison result at each specified position is output. The difference acquired when the position is specified may be output as a comparison result without change, and an image may be output after the image is further processed (for example, a difference is emphasized).

FIG. **18** is a flowchart illustrating a process example in which the block movement amount calculation module **1150** calculates the block size **1152** and the movement amount **1154**.

In step S**1802**, an enlargement or reduction ratio and a rotation angle (skew angle) which may occur in the recording module **120** or the reading module **1130** are acquired.

In step S**1804**, a block size is calculated.

In step S**1806**, a movement amount is calculated.

In step S**1808**, the block size **1152** and the movement amount **1154** are sent to the data collection/position estimation module **1140** and the comparison/collation module **1160**.

FIG. **23** is a diagram illustrating a process example of calculating the block size **1152**. In a case where rotation, enlargement or reduction is generated in the worst state by the recording module **120** or the reading module **1130**, a block size is set so that a pixel deviation is smaller than one pixel at each corner when centers of a block of the printing image **115** and a block of the read image **1135** match each other.

An example of FIG. **23** shows that a point **2350** in the printing image **115** is how deviated due to an error in the recording module **120** or the reading module **1130**.

The point **2350** is moved to a point **2360** due to a movement (during the maximum reduction in both scanning directions) **2355** caused by enlargement or reduction. In addition, the point is moved to a point **2370** due to a movement (counterclockwise) **2365** caused by skew. This case corresponds to a case where the maximum reduction occurs (the point becomes smallest), and counterclockwise rotation is the maximum.

The point **2350** is moved to a point **2340** due to a movement (during the maximum enlargement in both scanning directions) **2345** caused by enlargement or reduction. In addition, the point is moved to a point **2330** due to a movement (clockwise) **2335** caused by skew. This case corresponds to a case where the maximum enlargement occurs (the point becomes largest), and clockwise rotation is the maximum.

(1) When the maximum reduction (x-axis direction magnification: r_1, and y axis direction magnification: r_2) and the maximum skew (counterclockwise, rotation angle: α) occur in both of the scanning directions, a movement amount is calculated as in Equation (1) if a movement amount of a point on a diagonal line having the largest movement amount with a center of the block as an origin is set to (1,1).

$$\begin{bmatrix} \cos(\alpha) & -\sin(\alpha) \\ \sin(\alpha) & \cos(\alpha) \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \quad \text{Equation (1)}$$

A difference Δx of x at y=1 is calculated by using a straight line passing through the point **2370** and the original straight line. In the example of FIG. **23**, the difference Δx is defined by the point **2350**, the origin, the straight line passing through the point **2370**, and the straight line of y=1.

(2) On the other hand, when the maximum enlargement (x-axis direction magnification: r_3, and y axis direction magnification: r_4) and the maximum skew (clockwise, rotation angle: β) occur in both of the scanning directions, a movement amount is calculated as in Equation (2) if a movement amount of a point on a diagonal line having the largest movement amount with a center of the block as an origin is set to (1,1).

$$\begin{bmatrix} \cos(\beta) & \sin(\beta) \\ -\sin(\beta) & \cos(\beta) \end{bmatrix} \begin{bmatrix} r_3 \\ r_4 \end{bmatrix} = \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} \quad \text{Equation (2)}$$

A difference Δy of y at x=1 is calculated by using a straight line passing through the point **2330** and the original straight line. In the example of FIG. **23**, the difference Δy is defined by the point **2350**, the origin, the straight line passing through the point **2330**, and the straight line of x=1.

(3) y' and x' which cause Δx and Δy to become 1.4 are calculated. In addition, when a width and a height of the block are respectively indicated by W and H, Equation (3) is given.

$$W=2*\text{ceil}(x')+1,\ H=2*\text{ceil}(y')+1 \quad \text{Equation (3)}$$

Here, ceil( ) is a function which rounds up a decimal point or less.

Consequently, the block size **1152** (W and H of Equation (3)) may be calculated. For example, a width and a height of the block are respectively 100 pixels and 110 pixel.

Next, a description will be made of a process example of calculating the movement amount **1154** (a size of a search range) by using examples of FIGS. **24** and **25**. The movement amount **1154** calculated here is a movement amount at the most distant point.

In a case where rotation, enlargement, reduction, and movement all occur in the worst case due to the recording module **120** or the reading module **1130**, the movement amount **1154** is set so that a movement amount of a lower right corner in a certain paper size (for example, A3 elongation paper) is taken into consideration. In addition, the following coordinates have an upper left corner as an origin, a right direction and a lower direction as a positive direction, and a clockwise direction as a positive direction of a rotation angle.

Under a condition that a movement amount is the maximum in the upper right direction, with an upper left corner of a certain paper size as an origin, a movement amount of a lower right corner (for example, in the A3 elongation paper, coordinates (3897,5763) at 300 dpi) having the largest movement amount is calculated as in Equation (4).

$$M=M_{skew}+M_{size}+M_{shift} \quad \text{Equation (4)}$$

Here, M_{skew} indicates a movement amount caused by skew, M_{size} indicates a movement amount caused by enlargement or reduction, and M_{shift} indicates a movement amount caused by shift.

Here, M_{skew}, M_{size} and M_{shift} are respectively given as in Equations (5), (6) and (7).

$$M_{skew}=\begin{cases} 3897-\{3897\times\cos(\gamma)-5763\times\sin(\gamma)\}= \\ \quad M_{askew}\ (\text{pixel (main scanning direction)}) \\ 5763-\{3897\times\sin(\gamma)+5763\times\cos(\gamma)\}= \\ \quad M_{bskew}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (5)}$$

$$M_{size}=\begin{cases} 3897\times r_5-3897=M_{asize}\ (\text{pixel (main scanning direction)}) \\ 5763\times r_6-5763=M_{bsize}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (6)}$$

$$M_{shift}=\begin{cases} s_1\div 25.4\times 300=M_{ashift}\ (\text{pixel (main scanning direction)}) \\ s_2\div 25.4\times 300=M_{bshift}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (7)}$$

Here, γ indicates a rotation angle, r_5 and r_6 indicate an enlargement or reduction ratio, and s_1 and s_2 indicate a movement amount.

Therefore, Equation (8) is obtained.

$$M=\begin{cases} M_{askew}+M_{asize}+M_{ashift}=M_a\ (\text{pixel (main scanning direction)}) \\ M_{bskew}+M_{bsize}+M_{bshift}=M_b\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (8)}$$

A description will be made by using an example of FIG. **24**. FIG. **24** is a diagram illustrating a process example of calculating a movement amount.

A point **2450** is moved to a point **2460** due to a movement (the maximum in the upper right direction) **2455** caused by shift. In addition, the point is moved to a point **2470** due to a movement (the maximum enlargement in the main scanning direction and the maximum reduction in the sub-scanning direction) **2465** caused by enlargement and reduction. Further, the point is moved to a point **2480** due to a movement (counterclockwise) **2475** caused by skew. In other words, the maximum movement amount in the upper direction and the right direction at the most distant point (the lower right corner) from an origin **2410** (in FIG. **24**, the upper left corner) of an image **2400** is calculated.

On the other hand, under a condition that a movement amount in the lower left direction is the maximum, with an upper left corner of a certain paper size as an origin, a movement amount of a lower right corner (for example, A3 elongation paper) having the largest movement amount is calculated as in Equations (9), (10) and (11).

$$M_{skew}=\begin{cases} 3897-\{3897\times\cos(\theta)-5763\times\sin(\theta)\}= \\ \quad M_{cskew}\ (\text{pixel (main scanning direction)}) \\ 5763-\{3897\times\sin(\theta)+5763\times\cos(\theta)\}= \\ \quad M_{dskew}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (9)}$$

$$M_{size}=\begin{cases} 3897\times r_7-3897=M_{csize}\ (\text{pixel (main scanning direction)}) \\ 5763\times r_8-5763=M_{dsize}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (10)}$$

$$M_{shift}=\begin{cases} s_3\div 25.4\times 300=M_{cshift}\ (\text{pixel (main scanning direction)}) \\ s_4\div 25.4\times 300=M_{dshift}\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (11)}$$

Here, θ indicates a rotation angle, r_7 and r_8 indicate an enlargement or reduction ratio, and s_3 and s_4 indicate a movement amount.

Therefore, Equation (12) is obtained.

$$M=\begin{cases} M_{cskew}+M_{csize}+M_{cshift}=M_c\ (\text{pixel (main scanning direction)}) \\ M_{dskew}+M_{dsize}+M_{dshift}=M_d\ (\text{pixel (sub-scanning direction)}) \end{cases} \quad \text{Equation (12)}$$

A description will be made by using an example of FIG. **25**. FIG. **25** is a diagram illustrating a process example of calculating a movement amount.

The point **2450** is moved to a point **2440** due to a movement (the maximum in the lower left direction) **2445** caused by shift. In addition, the point is moved to a point **2430** due to a movement (the maximum reduction in the main scanning direction and the maximum enlargement in the sub-scanning

direction) **2435** caused by enlargement and reduction. Further, the point is moved to a point **2420** due to a movement (counterclockwise) **2425** caused by skew. In other words, the maximum movement amount in the lower direction and the left direction at the most distant point (the lower right corner) from the origin **2410** (in FIG. **25**, the upper left corner) of the image **2400** is calculated.

Based on the above description, the upward maximum value, the downward maximum value, the left maximum value, and the right maximum value of a movement amount may be calculated. For example, the upward maximum value, the downward maximum value, the left maximum value, and the right maximum value of a movement amount are respectively 67.41 pixels, 95.99 pixels, 58.73 pixels, and 62.47 pixels, and thus the upward, downward, left and right movement amounts of the block respectively become 68 pixels, 96 pixels, 59 pixels, and 63 pixels at minimum. In addition, actually, a movement amount is out of specifications (over specification) of the recording module **120** and the reading module **1130** and may thus be set to be larger by a predefined value. This value is a movement amount at the point **2450** which is the most distant point from the origin **2410**. Movement amounts at positions other than the point **2450** (search range) may be determined by the data collection/position estimation module **1140** based on the positions and the movement amount at the point **2450**.

With reference to FIG. **10**, a hardware configuration example of the image processing apparatus of the present exemplary embodiment will be described. A configuration shown in FIG. **10** is implemented by, for example, a personal computer (PC) or the like, and is a hardware configuration example including a data reading unit **1017** such as a scanner and a data output unit **1018** such as a printer.

A central processing unit (CPU) **1001** is a controller which executes processes according to a computer program which describes execution sequences of the respective modules described in the above exemplary embodiment, that is, the reading module **160**, the processing module **170**, and the comparison/collation module **180**.

A read only memory (ROM) **1002** stores programs, calculation parameters or the like used by the CPU **1001**. A random access memory (RAM) **1003** stores programs used for execution of the CPU **1001** or parameters which are appropriately varied in the execution and the like. They are connected to each other via a host bus **1004** constituted by a CPU bus and the like.

The host bus **1004** is connected to an external bus **1006** such as a peripheral component interconnect/interface (PCI) bus via a bridge **1005**.

A keyboard **1008** and a pointing device **1009** such as a mouse are input devices operated by an operator. A display **1010** includes a liquid crystal display, a cathode ray tube (CRT), or the like, and displays a variety of information pieces as text or image information.

An hard disk drive (HDD) **1011** has a hard disk built therein, drives the hard disk, and records or reproduces a program or information executed by the CPU **1001**. The hard disk stores the printing image **115**, the read image #1:161, the collation result **185**, and the like. In addition, a variety of computer programs such as various other data processing programs are stored therein.

A drive **1012** reads data or a program recorded on a removable recording medium **1013** such as a magnetic disk, an optical disc, a magneto-optical disc, or a semiconductor memory which is installed therein, and supplies the data and the program to the RAM **1003** which is connected thereto via an interface **1007**, the external bus **1006**, the bridge **1005**, and the host bus **1004**. The removable recording medium **1013** may be also used as a data recording region in the same manner as the hard disk.

A connection port **1014** is a port for connection to an external connection apparatus **1015** and has a connection unit such as a USB, or IEEE1394. The connection port **1014** is connected to the CPU **1001** and the like via the interface **1007**, the external bus **1006**, the bridge **1005**, the host bus **1004** and the like. A communication unit **1016** is connected to a communication line and executes a data communication process with external apparatuses. The data reading unit **1017** is, for example, a scanner, and executes a document reading process. The data output unit **1018** is, for example, a printer, and executes a document data output process.

In addition, the hardware configuration of the image processing apparatus illustrated in FIG. **10** shows a configuration example, and the present exemplary embodiment is not limited to the configuration illustrated in FIG. **10** and may employ a configuration which may execute the modules described in the present exemplary embodiment. For example, some modules may be constituted by dedicated hardware (for example, an application specific integrated circuit (ASIC)), some modules may have a form where they exist in an external system and are connected via a communication line, and plural systems illustrated in FIG. **10** may be connected to each other via a communication line and be operated in cooperation with each other. In addition, the hardware configuration may be incorporated into a copier, a facsimile, a scanner, a printer, a multi-function peripheral (an image processing apparatus having two or more functions of the scanner, the printer, the copier, and the facsimile), or the like.

In addition, the above-described program may be stored on a recording medium, or the program may be provided using a communication unit. In this case, for example, the above-described program may be understood as the invention of a "computer readable recording medium recording the program".

The "computer readable recording medium recording the program" refers to a recording medium which is used to install and execute the program and distribute the program, records the program thereon and is capable of being read by a computer.

In addition, the recording medium includes, for example, "DVD-R, DVD-RW, DVD-RAM, or the like" which is a digital versatile disc (DVD) and is a standard formulated by the DVD forum, "DVD+R, DVD+RW, or the like" which is a standard formulated by DVD+RW, a read only memory (CD-ROM), a CD-recordable (CD-R), a CD-rewritable (CD-RW), or the like as a compact disc (CD), a Blu-ray disc (registered trademark), a magneto-optical disc (MO), a flexible disc (FD), a magnetic tape, a hard disk, a read only memory (ROM), an electrically erasable and rewritable programmable read-only memory (EEPROM (registered trademark)), a flash memory, a random access memory (RAM), a secure digital (SD) memory card, or the like.

The above-described program or a part thereof may be recorded on the recording medium so as to be reserved or distributed, for example. In addition, the program may be transmitted by communication, for example, wired networks such as a local area network (LAN), a metropolitan area network (MAN), a wide area network (WAN), the Internet, an intranet, and an extranet, or wireless communication networks. Further, the program may be transmitted using a combination of the recording media, or may be carried on a carrier.

Further, the above-described program may be a part of another program, or may be recorded on the recording medium along with a separate program. In addition, the program may be recorded on plural recording media so as to be divided. The program may be recorded in any form as long as the program may be recovered through compression, encoding, or the like.

The foregoing description of the exemplary embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

1. An image processing apparatus comprising:

a correction unit configured to correct a tilt of each partial image data generated using a plurality of sensors reading a medium on which an image is formed using image data so that at least part of a reading region of each one of the plurality of sensors overlaps a reading region of an adjacent one of the plurality of sensors;

an extraction unit configured to extract extracted image data, from the image data,

wherein the extracted image data is extracted based on a position and a size at which the image data matches counterparts from the partial image data;

a comparison unit configured to compare partial image data corrected by the correction unit with the extracted image data extracted by the extraction unit; and

an insertion unit configured to insert a first blank space between the partial image data adjacent to each other so as to correct a tilt of the partial image data;

a generation unit configured to generate combined image data by combining the partial image data and the first blank space,

wherein the insertion unit is further configured to insert a second blank space having a size determined based on the first blank space and the tilt of the partial image data, between the extracted image data adjacent to each other, and

wherein the comparison unit is configured to compare the combined image data with image data into which the second blank space is inserted by the insertion unit.

2. The image processing apparatus according to claim **1**,

wherein the insertion unit is configured to insert the first blank space having a width which is set so that overlapping does not occur in a longitudinal direction of the partial image data after a tilt of the partial image data is corrected.

3. The image processing apparatus according to claim **1**,

wherein the comparison unit is configured to divide one of the combined image data and the image data into which the second blank space is inserted by the insertion unit into a plurality of rectangular images, search for corresponding positions of the plurality of rectangular images in another image, and compare the respective rectangular images with the another image at the searched corresponding positions,

wherein the insertion unit is configured to insert the first blank having a width which is set so that a width of the partial image data corrected by the correction unit and the first blank space is an integer multiple of a width of the plurality of rectangular images, and

wherein the insertion unit is configured to insert the second blank space having a width which is set so that a width of the extracted image data and the second blank space is an integer multiple of a width of the plurality of rectangular images.

4. The image processing apparatus according to claim **2**,

wherein the comparison unit is configured to divide one of the combined image data and the image data into which the second blank space is inserted by the insertion unit into a plurality of rectangular images, search for corresponding positions of the plurality of rectangular images in another image, and compare the respective rectangular images with the another image at the searched corresponding positions,

wherein the insertion unit is configured to insert the first blank having a width which is set so that a width of the partial image data corrected by the correction unit and the first blank space is an integer multiple of a width of the plurality of rectangular images, and

wherein the insertion unit is configured to insert the second blank space having a width which is set so that a width of the extracted image data and the second blank space is an integer multiple of a width of the plurality of rectangular images.

5. An image processing apparatus comprising:

a correction unit that corrects a tilt of each partial image data item which is a result of a plurality of sensors reading a medium on which an image of image data is formed so that at least part of a reading region which is read by each of the plurality of sensors overlaps a reading region of an adjacent sensor;

an extraction unit that extracts the image data at a position and a size at which the image data matches the respective partial image data; and

a comparison unit that compares partial image data corrected by the correction unit with extracted image data extracted by the extraction unit,

wherein the correction unit inserts a first blank space between the partial image data items adjacent to each other so as to correct a tilt thereof, and generates combined image data by combining the partial image data items with each other,

wherein the image processing apparatus further includes an insertion unit that inserts a second blank space having a size determined based on the first blank space and the tilt of the partial image data, between the extracted image data items adjacent to each other, extracted by the extraction unit, and

wherein the comparison unit compares the combined image data with image data into which the second blank space is inserted by the insertion unit.

* * * * *